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Introductory Note.

The following pages present the completed experimental investigations of the Department of Psychology of the University of Illinois carried on during the past few years. The work now in progress includes investigations in the psychology of sensation, in animal psychology and in the psychology of the learning processes. This latter series of investigations is being conducted both in the psychological laboratory and in several of the public school systems of the State. It is the purpose of the department to emphasize more and more this phase of its work. Because of an unavoidable delay two extensive studies by Professor J. W. Baird of the department were prevented from appearing in the present monograph. They will be published in a second monograph from the department and this it is hoped will be issued during the coming year.

S. S. C.

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THE COLOR PERCEPTION OF THREE DOGS, A CAT AND A SQUIRREL.

BY STEPHEN S. COLVIN AND C. C. BURFORD.

CONTENTS.

I. Review of the Literature on the Color Preferences of Animals.

The general question of the preference of animals for colorless and colored light has been the subject of speculation and investigation for the last forty years. It was maintained by Darwin and others[1] that the color of flowers attracted insects, especially bees, and was a great aid in cross pollination. Wallace also speaks of color preferences of certain animals. Grant Allen (2) in an extended treatise on the color sense speculates about the color reactions and preferences of animals and insects, but his treatise is not on a scientific basis.

[1] H. Müller, 'Alpfenblumen, ihre Befructung durch Insekten und ihre Anpassungen an dieselben.' Leipzig, 1881. For a later discussion see Andreae, E., 'Inwiefern werden Insekten durch Farbe u. Duft der Blumen angezogen?' *Beihefte z. botan. Zentralb.*, XV. (1903).

The first experimental work performed in this field was by Paul Bert (6) in 1869. He worked with *Daphnia* and tested their light and color reactions by means of the solar spectrum. He found that these little animals congregated principally in the yellow-green region. He concludes that all the animals tested saw only the same spectral rays as we see; he also asserted that through the whole range of vision brightness differences of the same colored rays are identical for them and for us. He attributed the preference for the yellow-green end of the spectrum to a liking for the greater brightness and not to any actual color preference. But he made no attempt to isolate and separate the brightness and the color factors.

A more thorough piece of investigation was performed by Sir John Lubbock (33). He investigated the color and light reactions of *Daphnia pulex* by a method similar to that which was employed by Bert, though he took much greater care. He found that the greatest preference of these animals was for green; he also tested their limit of light sensitivity and found that they reacted to the ultra-violet rays, which showed a pronounced effect as compared with black, although this effect fell off rapidly as the rays approached their outer limit. He also tested ants to find how they were affected by different colored lights and media. The ants showed an antipathy for the violet end of the spectrum and particularly for the ultra-violet. He found in one test that when all the pupæ had been removed from the ultra-violet zone in which they had been placed, the ants then directed their attention to the violet zone, some pupæ being carried into the dark and some into the red and yellow zones. He further found that the ants chose blue in preference to the ultra-violet, thus disproving Bert's statement that animals see only the spectral rays that are visible to us. Lubbock also experimented on bees and found certain color preferences. The chief defect in his method was that he did not carefully distinguish between intensity and color stimuli.

Merejhkowsky (35) tested lower crustaceans with a somewhat more careful method and concluded, because they did not react to color differences, that they were unable to distinguish color. He found that they exhibited a light preference.

He states that they distinguished well the intensity of the ether vibrations, their amplitude, but not their length; that there is a great difference between the inferior crustaceans and man in the manner of the perception of light, for while we see different colors they do not see a single color in its various intensities. We perceive color as color, they perceive it as light.

The most careful series of experiments in this particular field were performed by Vitus Graber (18, 19, 20) in the early eighties. His principal investigations are described in a monograph of some three hundred pages. In these he tested the light and color reactions of more than fifty different animals, including the pig, dog, cat, rabbit and porpoise among the higher vertebrates; the gold-finch, common sparrow, bull-finch, raven, dove, cockatoo and guinea-hen among birds; the triton and the frog among amphibians; the lizard, the slow-worm, and the terrapin among reptiles; a large number of insects including bees, ants, crickets, fleas, house-flies, also spiders and a number of worms. These animals were tested for the most part with two colors at a time and their preference was determined by the color which they sought. Also some experiments were made by presenting several colors at once. The colors used being pure red, yellow-green, and blue with ultra-violet and black and white.

Some of the specific questions which Graber attempted to investigate were the following: (1) To what extent do animals distinguish degrees of light intensity, and what degree is most agreeable? (2) How far do animals distinguish different colors and which are most agreeable? (3) Has the visible spectrum in the case of certain animals a greater extent than in the case of man, that is, are ultra-violet and likewise infra-red visible to them and do they appear to them as particular qualities? (4) Are certain animals blind to parts of the spectrum visible to us. He found that among the animals tested by him only a few failed to react to color, while the remainder showed a pronounced, in some instances an astonishing, preference for certain qualities of light. Most of the animals that failed to react were high up the scale. Among these were the cat, the porpoise, the rabbit, the hen, the parrot and the tortoise. He

found among dogs only certain animals that showed a marked light or color reaction; others seemed entirely indifferent. He concludes that there is no general agreement in color preference among animals; that among some animals there is no absolute color preference, but that the preference varies according to the arrangement of the colors compared; that the contrast effect of two colors is greater in proportion to the difference of the wave-length of the colors; that most animals possess some sensitivity for the ultra-violet rays; that with a few exceptions animals with a preference for white also have a preference for blue; that color causes pleasurable emotions in animals or the opposite, and that we are justified in speaking of a color taste (*Farbengeschmack*).

Graber also conducted a series of experiments with certain sightless and blinded animals. The results here were pronounced, in some instances almost startling. His first experiment with the common earthworm showed that it was sensitive not only in the anterior portion as had been previously held, but over its entire body, and this even when it was in a mutilated condition. He also worked with the blinded triton and with the blinded cockroach.[2]

This investigator later carried on a series of experiments with a number of marine animals, confirming in general the results of his previous researches.

A large amount of attention has been directed to the study of the effect of light and color upon the reaction of organisms far down the biological scale. In 1879 Englemann (12, 13) published a study on the stimulation of contractile protoplasm by sudden illumination, and three years later another on the light and color perception of lower organisms. In 1878 Strasburger (54) discussed the influence of light and warmth on swarm-spores. He found positive phototaxis for all colored swarm-spores in weak light. All swarm-spores do not react in the same way. Some showed positive reactions in strongest lights, but most showed a negative reaction if light is sufficiently intense.

[2] He attributed this sensitivity in the case of eyeless and blinded animals not to a chemical activity, but to an actual dermal sensitivity to the light rays.

Fatigati (15), in a study of the influence of various colors on the development and respiration of infusoria, concludes that the respiration of these animals is more active in violet than in white light and less active in green than in white.

During the last ten or fifteen years the literature on the subject has multiplied until it is very extensive, and no attempt will be made in this study to cite more than characteristic investigations here and there, and to state some general results. It has been found that amœbæ show definite reactions to light, their movements being checked by a light of strong intensity, white light causing them to come to rest. Blue affects them in the same way. Red light, according to Englemann's experiments, does not interfere with their activity.

Harrington and Leaming (22) state that amœbæ stream in the presence of red light but streaming is retarded, stopped or reversed by rays from the violet end of the spectrum. The effectiveness of various lights as inhibitors of protoplasmic flow diminishes in the order named; white, violet, red. Enucleated amœbæ stream in red light and cease to stream in violet or white light.

Wilson (62) studied the heliotropism of *Hydra*, and found that these animals collect in blue light but show no other color preference, except a slight one for green. Blue is preferred to white. The animals are restless except under these conditions. The animals move toward the light side of a vessel in a direct way suggesting purpose. In powerful light *Hydra* show negative reaction. Hertel (23), after experimental investigation of the influence of the ultra-violet rays upon *Hydra* and *Paramecium*, found that *Hydra* contract under the influence of these rays, which soon kill them. *Paramecia* do not react to ordinary light but they are sensitive to the ultra-violet rays. He also found that colored infusoria show positive and negative reactions to light. Stentors react negatively and *Euglena* positively.

Jennings (30) states that most bacteria do not react to light but "the purple bacteria are sensitive in different degrees to lights of different colors, tending to gather in certain colors more than in others. The largest number collect in the ultra-

red rays. There is another collection in the yellow-orange, while a few are scattered through the green and blue. None are found in the red, the violet or ultra-violet. . . . It is a most interesting fact that the colors in which the bacteria collect are exactly those which are most absorbed by them, and are also those which are most favorable to their metabolic processes."

G. H. Parker and L. Arkin (40) conclude that the earthworm *Allolobophora fœtida* is negatively phototactic to light of moderate intensity. These results are also in accord with the findings of Miss Smith (53). Adams (1) concludes that earthworms are negatively phototrophic in strong lights but positively phototrophic in faint lights. He says: "Earthworms retreat into their burrows during the day time because of their negative phototropism. They emerge at night, not so much because of darkness as because of the positive phototropism of faint light."

Among investigations on the influence of light on sightless animals during the last few years may be mentioned that of Parker and Burnett (41). They conclude that "Planarians without eyes react to the directive influence of light in much the same way as those with eyes."

Among investigations since the work of Graber on insects is that of Nagel (38). He handled the results of Graber critically and doubts the legitimacy of the conclusion that the reaction of blinded and eyeless animals to light is a genuine dermal light sensitivity. He believes that the reactions may be explained as due to chemical excitation.

Investigations of the Peckhams (42) in regard to spiders include a test of their color sensitivity. They conclude that these animals see colors, and find an indication of a preference for red, but no positive dislike for blue.

In 1896 Axenfeld (4) tested the influence of the Röntgen rays on insects. He found that the fly was very sensitive to these rays and reacted to them negatively.

Yerkes (63) in a careful study of the reactions and reaction time of medusa *Gonionema murbachii* to photic stimuli concludes that increase in light intensity uniformly causes a motor reaction in quiescent individuals and the inhibition of move-

ment in active individuals. Decrease in light intensity usually causes the inhibition of movement in active animals, but rarely does it act as a stimulus in the case of resting animals. Strong light is injurious to *Gonionema,* and a few hours' exposure is usually fatal.

Among recent studies of the response of higher animals to light may be mentioned that of Ellen Torelle (58). In her experiments with the frog, she concludes that these animals " respond to light coming from above and from below as well as from the side. When a bank of sand is interposed between the frog and the light they crawl over this and move to the source of light. The frogs turn away from red light and move towards blue light. They move toward green and toward yellow light, but are not definitely orientated by either. When a red light is admitted at one end and green light at the other end of a receptacle the frogs move from the red to or toward the green. When red and yellow lights are apposed in the same way, movement is from the red to the yellow. When red and blue are apposed, movement is immediately toward the blue. When white light is admitted at one end of a receptacle, and the frogs are given a choice of a red or a blue environment, they move, in most cases, into the blue, and remain in it longer than they do in the red. When one half of the entire receptacle is blue and the other half is red (no white light being admitted), movement is from the red to the blue."[3]

Rouse (49) in 1905 made a study of the respiration and emotion in pigeons. He tested the animals in regard to their color preference and likewise in regard to their reactions to light as shown by a detailed study of their respiration. The colors selected were red, yellow, green and blue. The results show no pronounced color preferences, nor reactions for the various animals tested. It may be mentioned in this connection that Graber's study with these animals showed negative results as to intensity and color preferences.

Kinneman (31) in 1902 published an experimental study on

[3] Graber, in his experiments, found frogs to be negatively heliotropic, and to prefer red to blue.

the mental life of monkeys. In this he made a test of their color preferences by feeding the monkeys colored candies after the method of Garner (16), but reached no definite results. Another test was made under more favorable circumstances and with a different method. One of the animals tested, a female, showed no indication of preference. The other, a male, "appears to have a preference for bright colors, but blue seems to be discriminated against."

Garner in summing up his tests states that "all monkeys do not select the same color at different times, but I think that bright green is a favorite color with the Capuchins, and their second choice is white." In experiments with the Cebus monkeys and a few Macaques he concludes that "they are generally attracted by all brilliant colors."

The color preferences of infants have been studied in connection with their color discrimination. Preyer believes that yellow comes first with brown and red later; green and blue last.

Binet[4] (8) places red first in the series. Compayré concludes that yellow and red are the two colors most easily recognized by little children and that the child likes soft colors less than strong ones.

Baldwin (5) in his test with his children gives the following order of preference: blue, red, white, green, brown. He made no test with yellow, and found but slight difference in the attractiveness of blue and red.

Nagel (39) more recently conducted a series of experiments in color discrimination with his infant son, then two years and four months old.

"The child at once designated red, not only the spectral red, but likewise bright and dark as well as unsaturated reds; he included in his choice also pink, purple and occasionally orange.

"Green was learned without much practice and was not afterward forgotten; similarly, a few days later, violet and black.

[4] Binet's order of preference is red, blue, orange, rose, violet, green, white and yellow.

" The recognition of gray and blue developed rather more slowly.

" Blue was forgotten again in two days; that is the name was not used, although the color was only very infrequently confused with other colors." Nagel gives the following scale of preferences:

Green, Violet, Red — About equal in rank in the series.
Black.
Yellow, White, Gray — About equal in rank in the series.
Blue.

Recently considerable discussion has developed in regard to the interpretation of the reaction of various lower organisms to light and to other stimuli. Davenport (11) in his Experimental Morphology says: " We see that organisms respond to light and that this response, exhibited in movements, is not of a widely different order from the disturbances produced in metabolism, which in turn are of the same order as the chemical changes produced in our laboratories upon non-living substances. In a word, response to light is the result of chemical changes in the protoplasm wrought by light." Thus the reaction of these lower organisms is explained as in no way being due to consciousness but as being the result of purely physical causes.

The attempt to mechanize the life of these animals has been definitely formulated in recent years under the physiological theory of tropisms. Loeb (32) has been one of the principal supporters of this theory, also Bethe and Verworn (59) who states that " the phenomena of chemotaxis, thermotaxis, phototaxis and galvanotaxis follow with mechanical necessity as the simple results of differences in biotonus, which are produced by the action of stimuli at two different poles of the free living cell." Holt and Lee (29) also support this theory. One of the chief opponents of this theory as an adequate explanation for a large number of the activities of lower animals in Jennings.

Royce (48) explains what is implied by tropic reactions as follows: "The general character of such reactions is that they determine, in an organism of a given type, a certain characteristic normal position of the organism with reference to its environment, and certain equally characteristic tendencies on the part of the organism to recover its normal position when it is for any reason temporarily lost, and to assume, in the presence of stimuli of certain types, certain directions of movement and certain attitudes which may persist through a great variety of special activities." Jennings quotes Loeb to the effect that "The tropisms are identical for animals and plants. The explanation of them depends first upon the specific irritability of certain elements of the body's surface, and second on the relations of symmetry of the body . . . animals are led without will of their own either toward the source of the stimulus or away from it." As opposed to this view Jennings cites the work of Holmes (27), Miss Smith and others to show that the reaction of certain of the lower animals "indicate adjustments as results of trial and error similar to that employed by higher forms." This is found to be true of the earthworm and of the leech and the larva of the blow-fly.

Harper (21) in a subsequent paper takes up the work of Holmes and concludes that the random movements of an earthworm under light stimulation are of an entirely special character due to causes inherent in its structure.

Radl (44) and Bohn (9) after careful study with various animals find themselves unable to accept the theory of tropisms as an explanation for many of the reactions of the organisms investigated.

Jennings is quite positive that the behavior of lower organisms brings in the factor of consciousness as a necessary explanation for many of their activities.

He believes that the activities of *Paramecium* indicate that they are directed by consciousness. "Still stronger, perhaps, is this impression when observing an amœba obtaining food. The writer is thoroughly convinced, after long study of the behavior of this organism, that if amœba were a large animal, so as to come within the everyday experience of human beings,

its behavior would at once call forth the attribution to it of states of pleasure and pain, of hunger, desire and the like, on precisely the same basis as we attribute these things to the dog."

It is evident from the data afforded by the above-mentioned studies that, even in the lowest organisms there are reactions to light and color. Whether these reactions are purely chemical and mechanical or whether with them there is also a conscious element, will perhaps continue to be a debatable problem. In the case of the higher organisms investigated, a conscious basis for their reaction to color and light would hardly be contested. The investigations, however, that have been cited in regard to animals below man have hardly gone farther than to determine the color preferences of the animals experimented with and have not taken up the question of an actual preception or discrimination. Graber, indeed, concluded from his experiments that certain animals at least have a color sensation and perception and that these are more extensive than their color preferences, as manifested by their reaction to color; and also in some instances this perception is finer. However, Graber's experiments if strictly interpreted, can be taken to show hardly more than that many animals find certain intensities and qualities of light pleasurable or unpleasurable. This fact by no means proves conclusively that animals have more than a rudimentary sensitivity in these directions. That they have a clear perception of light and color differences is more or less of an assumption, and the same is true for practically all the other investigations.

Some Recent Studies of the Color Discriminations of Animals.

The definite problem which the present study attempts to present in a preliminary way is not primarily the question of the color or light preference of animals, but of their actual power of perception and discrimination. An animal might well be sensitive to color and light differences but possess no powers of discriminating these or of recognizing them as such.

Until recently no direct work has been done in determining the ability of various animals to actually distinguish colors.

During the last few years, however, a number of studies have appeared which touch upon this problem. Miss Washburn and Bentley (61) have studied the color discriminations of the creek chub. The method used was intended ' to test color-discrimination by establishing, if possible, an association between a certain color and food.' The problem was worked out by two sub-methods, namely: (1) The method of inhibition, and (2) the method of choice. In this first method two colors. a dark red on one pair of forceps and a bright green on the other, were used. A live grasshopper was held in the forceps, only one of which was presented at a time. "The fish was allowed to take the food from the red forceps; but when it snapped at the green pair, the food was quickly withdrawn." No constant difference was noticed in the response of the fish to these two colors. The second method was then employed. In this both pairs of forceps were presented at the same time, the red baited and the green empty. After the forceps had been put in position a gate was open and the fish was allowed to swim into a compartment and secure food from the forceps. Several tests were made each day with the red forceps baited and then from one to four tests were made with neither forceps baited. The results were as follows: Red with bait chosen first 169 times; green without bait thirteen times; red chosen without bait forty-two times; green chosen without bait two times. Later blue was substituted and thirty tests were made with the red baited twenty times and ten times unbaited. The red was selected every time in preference to the blue. Later the bait was placed in the green forceps. The results of sixty-nine tests show the green chosen thirty-five times and the red eighteen. The conclusion is reached that the fish "distinguishes red from green and from blue pigments, the discrimination being independent of the relative brightness of the colors."

Rouse in his study of the mental life of the pigeon made an investigation of the animal's color discriminations. His method likewise was "to investigate the animal's ability to utilize colors in finding food. . . . Six boxes were used throughout and each was covered with paper of a different color; red,

yellow, green, blue (Bradley's standards, except red, RO being substituted), gray and black. The boxes covered with black and gray paper were employed merely to complete the group of six." The results show a positive color discrimination. The proper box was chosen more often than the empty one, but never oftener than the other five combined. The finest discrimination was with green, with a hundred correct choices. The next with red with eighty-eight correct choices. The next with yellow, eighty correct choices. The lowest with blue, seventy-one correct choices. The author further states: "To test the animal's ability to discriminate shades of colors in finding their food, two birds were used, with four boxes, each covered with a different shade of red paper, and two with the boxes covered with green paper. The brightness of the different shades was not measured, but to the eye it seemed to be equal in each of the cases. The food was placed in the box having the most nearly saturated color, and twenty-four trials in series of six, as before, were given each bird. The results were quite similar to those secured with different colors. With the red shades there were twenty-two choices of the best saturated shade to eight, ten and eight, respectively, of the other three; and with green, twenty-one to nine, ten and eight. The forty-three correct choices were distributed from series 1 to series 4 as follows: 7, 11, 12, and 13, which shows learning as before."

Porter (43) tested the color discrimination of the English sparrow and of the cow bird. "Six glasses were covered with the Bradley colored papers, a dark gray, a light gray, a bright yellow, a dark blue, a light green and a dark red." The glass to be chosen contained food. Both birds learned to distinguish colors at about an equal rate. There was by no means a perfect color discrimination. The English sparrow showed some superiority in his discrimination of the blue. The cow bird seems to have been slightly superior in the discrimination of yellow and red. Green was about equally well distributed.

Himstedt and Nagel (26) found that a dog tested by them discriminated between red and blue when several sharply different degrees of brightness were present, and Himstedt in a

subsequent test found that the animal could recognize the difference between blue and green and red and green.

Kinneman's study with monkeys included not only an inquiry into their color preferences, as previously stated, but also an investigation of their actual color perception. Kinneman made a large number of tests, nearly seven thousand in all. The brightness of the colors was determined by Rood's ' flicker method.'

The results of the tests the author summarizes as follows:

" 1. There can be no doubt that monkeys perceive colors.

" 2. Two grays having a given degree of difference in brightness are not discriminated as well as two colors having an equal difference in brightness.

" 3. For accurate discrimination of difference in brightness a difference of about thirty-five degrees or none per cent. of the white constituent of the gray is necessary.

" 4. The monkeys are able to distinguish colors from grays though the brightnesses are the same.

" 5. The male appears to have a preference for bright colors, but blue seems to be discriminated against.

" 6. In two instances there were indications of at least a low form of general notion."

In this connection may be also mentioned a statement by Gates (17) in regard to the color discrimination of dogs. He tested these animals with pans of various colors and shades, and with colored metal plates. Under the pans of a given color or shade food was placed and the animals were required to select the proper pan, among many others of different colors and shades. The metal plates were so arranged that certain ones were electrically charged so that the animals received a shock whenever they stepped on these. The writer concludes that the animals tested showed very fine color discrimination. Not a sufficient account is given of the test to judge of its accuracy, or the value of the conclusions reached.

Cole (10) succeeded in training raccoons to distinguish cards of different colors and brightnesses. Considerable difficulty was experienced in teaching the animals to distinguish between blue and yellow and red and green.

Probably the most important contribution to the problem of light and color discrimination in animals is to be found in the recent work of Yerkes (64) on the dancing mouse. The animals were taught to associate two compartments differently illuminated with an electric shock. In the first series of tests the object was to determine whether the animals could distinguish between intensities. It was clearly established that they could do this. In a second series an attempt was made to discover if they possessed color discrimination. In these latter experiments light was filtered through colored screens. Intensities were controlled by the moving backward or forward of electric lamps, their position being measured in reference to the reaction box by a millimeter scale. Brightness was easily regulated, but could not be accurately measured. The only means of comparison was the eye of the experimenter, " and as subjective measurement was unsatisfactory for the purpose of the experiment, no attempt was made to equalize the amount of brightness reduction caused by the several filters." By varying the position of the lamps, a color at one time could be made to appear very much brighter than another and again very much darker, and thus it was sought to eliminate the factor of brightness in judging the ability to discriminate colors.

The writer concludes that " although the dancer does not possess a color sense like ours, it probably discriminates the colors of the red end of the spectrum from those of other regions by difference in the stimulating value of light of different wave-lengths, that such specific stimulating value is radically different in nature from the value of different wave-lengths for the human eye, and that the red of the spectrum has a very low stimulating value for the dancer."

II. Method and Apparatus.

1. *Treatment of Animals.*

The animals used in the present experiment were three dogs, a kitten and a squirrel. A second kitten was also used a few weeks, but as it proved to be unable to learn the simple movements needed in the experiment it was disposed of.

The animals were in all cases given as much liberty as was possible. One dog was allowed his entire freedom in exactly the same manner as he was accustomed to have it. The other two dogs were at first confined in a large well-lighted room, one dog having been placed in the room some time before the experiment began, so that he was perfectly habituated to the room. The second dog was brought in a short time after the experiment was undertaken, but at no time did it seem to be impatient or uncomfortable. Later these two animals were placed in a large and comfortable box stall, well lighted and aired. The kitten was kept in an ample, well-lighted room; it soon became accustomed to its surroundings, although at first it naturally showed somewhat more restlessness than did the dogs. The squirrel lived in a large room in which he had been confined several weeks previous to the beginning of the experiment. This room also was well-lighted and contained a pile of lumber over which the little animal could scramble.

The idea of giving animals as much freedom as was consistent with the experiment was always kept in mind, so as to avoid as much as possible the chief objection often raised against the experimental method of studying animal behavior, namely, that it subjects animals to very abnormal conditions such as close confinement, extreme hunger, etc., and that it does not give animals full opportunity for the display of their intelligence. American psychologists seem to have fallen into this error. The work of Thorndike (55), excellent though it is in introducing the scientific method and in banishing popular observation and anecdote in studying animal intelligence, has been especially criticized in this respect. He confined hungry cats and dogs in narrow cramped boxes from which they could escape to food by learning to operate some simple mechanical devices. It is needless to say that a healthy dog or cat cannot stand such close confinement without becoming worried and excited almost into a frenzy. In the present study the experimenter has often noticed a pronounced dislike of confinement on the part of the animals. It was sometimes necessary to confine the kitten for a minute or two in a small box while the

apparatus was being adjusted. Even this temporary captivity was enough to make the animal mew and paw for freedom. Again the kitten was extremely cautions in getting into boxes, even to the extent of refusing to enter a box which contained food. The squirrel, on the contrary, would search the interior of a box for food, keeping, however, a sharp watch. He too disliked captivity as was proved when he was taken out of his usual quarters and placed in a squirrel cage out of doors. He became excited and when released in his accustomed room, hastened to his nest and could not be induced to come down for food for two or three days.

Other American observers, as Kinnaman and Small (51), have experimented upon animals in captivity, but none of them seem to have gone to the extent to which Thorndike did. The work of such psychologists as Morgan and Hill in England and as Mills in Canada, who observed animals out of doors and in their natural environment, offers decided advantages for gaining an insight into the intelligence of animals. If for practical reasons confinement is necessary it should be made as free as possible.

2. *Nature of the Experiment.*

The entire experiment covered a period of about ten months, beginning in October, 1904, and continuing until the following August. Three different sets of experiments were conducted. In the first series all the animals were tested as to their ability to discriminate between a standard red and other colors of various hues and degrees of saturation. In the second series one of the dogs was similarly tested, but with various colors other than red used as a standard. In the third series the attempt was made to determine the animal's ability to abstract the standard red from the particular receptacle on which it had been presented in the first series of experiments, and to recognize it under various and novel conditions.

In the first experiment the method of testing the extent of the color discrimination of the dogs and the squirrel was by allowing them to choose between two painted boxes, both containing equal amounts of food, one of which could be opened

and food secured from it, while the other one could not be opened. Two painted pans instead of boxes were used in the experiments with the kitten. A constant color, namely, a saturated red, was chosen for the receptacle which the animal could open, while the color of the second receptacle was varied from time to time. Thus the color red became directly associated with the securing of food and was consequently discriminated from the other colors in proportion as successful efforts to obtain food exceeded expectancy. The boxes and pans, other than red, were changed from time to time in the following order: green, blue, yellow, orange, violet, red-orange, red-red-orange, and red No. 2.

This latter color differed from the standard red by being reduced in saturation approximately ten per cent. In other respects it was the same as the standard. The various pigments used were matched in intensity with the medium gray which stood first in the series of tests. This, of course, did not absolutely prevent a brightness discrimination on the part of the animal tested. The fact that all these colors appeared of equal intensity to the human eye does not necessarily mean that they have the same brightness value for all animals. We know that for color-blind persons the reds and green may have different brightness values than for the normal human eye, and there may be many small degrees of brightness variation even within the range of the 'normal' color-vision of the human eye. Yerkes's experiments with the dancing mouse, as previously stated, seem to show conclusively that the same wave-lengths may possess a decidedly different value for the human and for the animal eye.

The boxes used in working with the dogs were 15 x 10 x 8½ inches. A door 8 x 8 inches was placed on the front of each box. The doors of the red box could be opened when the animals moved a small latch from a horizontal to a vertical position. There was a similar latch upon the inside, the two moving together, thereby keeping the door from being pushed in or pulled out by the animals until the simple act of moving the latch was accomplished. The door was supported by leather hinges and when free, could be either pushed in or

pulled out and the animals were then able to obtain the food. The other boxes were exactly like the standard red in size and in every detail except in color. Each of these boxes had a door and a horizontal latch similar in outward appearance to the door and the latch of the red box, but the latch was securely fastened by being nailed, and the door could not be opened.

In experimenting with the kitten a red pan pierced by numerous holes, and 1¾ inches high and 7 inches in diameter at the top, was inverted over a small red wooden platform 14 by 13 by 1¾ inches. This pan had a slightly projecting edge, which rested, since the pan was inverted, immediately upon the platform. Into this projecting edge the kitten learned with considerable skill and nicety of adjustment to insert its claws and to pull the pan a few inches aside until it tipped over the edge of the platform and exposed the food, which had been covered by the pan. A second pan of different color but of equal size and pierced by an equal number of holes and inverted over a similar platform, was rendered immovable by small nails passing through the projecting edge of the pan into the platform below.

The boxes which the squirrel opened were exactly like those presented to the dogs except that they were much smaller being 7¾ x 6½ x 5½ inches with doors 4¾ x 4½ inches. The door of the squirrel's box was placed at the top instead of in front of the box and the animal learned to open it by mounting upon the door, turning the latch and sinking with the falling door into the interior of the box, where he found nuts and fruit awaiting him.

The animals were in all cases given some training in opening the receptacles, as the mere act itself was only incidental to the issue of the experiment. With this assistance all the animals except the second kitten learned to open the receptacles in a few days and the experiment was never greatly delayed on that account. The second kitten failed to learn in several weeks with considerable instruction to remove the pan and perform simple acts which its companion learned in five or six days.

Care was taken throughout the experiment to prevent the animals from associating a certain part of the room with the

procuring of food. The boxes or pans were in all cases placed in a part of the room where the light was equal upon both receptacles, but the boxes or pans of a certain color were not placed habitually in one place. They were interchanged on different trials although not always on successive trials.

Another precaution taken was often to replace the standard red box or pan in use with another red receptacle freshly painted. This was done in order to guard against the possibility of the animal determining in any way by the odor which box had been the one most frequently opened. As the introduction of the freshly painted receptacle caused no marked change in the curve, it cannot be supposed that the odor left by the animal's more frequent pawings of the standard red receptacle played any part in the choice.

The conditions of the experiment then were such that all possibilities of a discrimination between the boxes on the basis of odor were excluded; associations with place were eliminated by change of position of the boxes, part of the time the test box being on the right and part of the time on the left. Intensity discrimination was avoided as far as possible by matching the colors in intensity with medium gray. The boxes were all equally and uniformly illuminated by diffused sunlight and the animal when tested approached the receptacles at a place equally distant from each. Under these conditions it seems reasonably certain that all choices were based on an actual color discrimination between the receptacles used.

As has been stated, the standard receptacle (box or pan painted red) was tested with each of the other receptacles (nine in all). After the animal had learned to make the proper discrimination between the standard red and each of the other receptacles, all the receptacles that had been previously used in the experiment were placed in the room and arranged in a semicircle, so as to be equidistant from the animal at the beginning of the test. It should be mentioned in this connection that in all the tests the animal was first introduced to the receptacles at a position some twenty feet removed and at such a point that the various receptacles should be equidistant from this position. Two methods of tabulating

the results of the animals' choices were employed. By the former the animal was recorded as having failed in the test, if on being introduced to the receptacles he merely approached or sniffed at the wrong one. By the later method he was credited with a right choice, if he approached the wrong box or pan and then without attempting to open it, went to the right receptacle and opened it, obtaining food. In this second case no error was recorded unless the animal actually attempted to open the wrong receptacle.

III. Results.

1. *Experiment I.*

(*a*) *Dog No. 1.*—The first set of experiments with this animal covered a period of one hundred and fifty-eight days. He was tested with gray, green, blue, yellow, orange, violet, red-orange, and red-red-orange and red No. 2 in the order named and followed by all the boxes. After the first week he had learned well the discrimination for gray, and from that time on the curve drawn by the first method never fell below expectancy for the entire period this box was presented. On four occasions it touched fifty per cent., but on the whole was clearly above expectancy.

When green was introduced the curve fell somewhat for two days, but quickly recovered. The lowest point reached with this color was fifty-nine per cent. On four days it was at one hundred per cent.

Blue also shows a high average. It fell slightly when this color was first introduced, but immediately rose to one hundred per cent., where it remained for the majority of the trials. With yellow the results were not so high. Once with this color the curve fell below expectancy, but altogether maintained a high average.

The test with orange was always above expectancy, and the curve continued to mount through violet, red-orange and red-red-orange.

On the introduction of the red just observably different from the standard, there was a fall to fifty per cent. for two

succeeding days, then a rise to fifty-seven per cent., a fall to fifty-six, a rise to sixty-four, a fall to fifty, a rise to one hundred, a fall to fifty-five and then to fifty, followed by a rise to one hundred and a fall to fifty.

When all the boxes were employed simultaneously the animal at first was clearly confused and the curve fell, yet never went as low as expectancy (ten per cent.). The lowest point touched in this last test was forty-two per cent., the highest one hundred, which was reached on the last two days of this test.

When the results were computed by the second method the curve was still higher. Not one failure was recorded for blue, the average throughout being one hundred. Only two failures were recorded for yellow, one for orange, one for violet, none for red-orange, one for red-red-orange, three for red just observably different, while with this color there were seven days on which the hundred mark was reached. With gray and green the results were high above expectancy, but considerably lower than with the succeeding colors.

The results of the above tests expressed by both methods in per cents with mean variation for each average follow:

	Av. 1.	M. V.	Av. 2.	M. V.
Gray	66.7	14.4	81.7	14.9
Green	84.9	11.0	89.0	10.0
Blue	93.1	11.7	100.0	0.0
Yellow	84.4	17.4	91.0	17.1
Orange	77.5	14.9	98.3	2.7
Violet	87.8	13.3	97.2	5.2
Red-orange	91.4	9.7	100.0	0.0
Red-red-orange	93.4	11.8	98.4	2.8
Red No. 2	64.4	14.9	81.3	18.1
All	67.8	17.4	67.8	18.4
Average	81.1	13.6	90.5	8.9

(*b*) *Dog No. 2.*—The first experiment with this animal occupied one hundred and sixteen days. The colors were presented in the following order: green, blue, yellow, orange, violet, red-orange, red-red-orange, and red No. 2, followed by all the boxes. The results computed by the first method show this animal to have been inferior in accuracy of discrimination

to dog No. 1; but the curve is clearly above expectancy. The first three days showed fifty per cent. of correct choices, then the curve rose to one hundred per cent., but soon fell again to fifty per cent., mounted to sixty-six, then fell to fifty-seven, where it remained for two days.

At this point blue was introduced and the curve fell to fifty-four per cent., then to fifty-three, then to fifty. After this it gradually rose and for some days remained at one hundred per cent.; it then fell again, rose and fell once more, but finished high.

On the introduction of yellow the curve fell to sixty-one per cent., but then, after some fluctuation, rose to one hundred, where it continued for six days. It soon fell to fifty but rose, fluctuated and finished relatively high.

Orange when introduced caused a fall to sixty per cent., followed by a rise to one hundred; later a fall which reached as low as sixty-three per cent., followed by a number of perfect choices and then a fall to seventy-one per cent.

Violet at first caused a rise to one hundred per cent., with a later fall to sixty-seven per cent. for several days and a subsequent return to one hundred per cent., with a later fall to eighty-seven per cent.

When red-orange was introduced there was a fall of sixty-seven per cent., then a rise to one hundred, a second drop to seventy-five per cent. and a recovery to one hundred per cent.

Red-red-orange caused a fall to seventy-eight per cent.. After this there was a rise to one hundred per cent., followed by an abrupt drop to fifty per cent. Then the curve fluctuated with a maximum at eighty-eight per cent. and a minimum at sixty-seven. It ended at eighty-three per cent.

With the introduction of the red just observably different from the standard there was a fall to fifty per cent., a rise to sixty-seven and a fall to thirty-eight, then marked fluctuations, ranging from eighty per cent. to twenty-five per cent. The test ended with the curve at fifty per cent. On the introduction of all the boxes the curve fell to forty-seven per cent. It then rose to sixty-eight per cent. and at once fell to eighteen per cent. There was, however, an immediate recovery with a final rise

to one hundred per cent. The test ended at eighty per cent.

The tabulation by the second method showed a considerably higher average throughout. This was very marked with green and yellow, where the number of successful trials was far in excess. With blue the lowest point reached was sixty per cent., the next lowest seventy-one. There were several days when the curve stood at eighty per cent. Once it stood at eighty-nine per cent. and the later days of the experiment without fluctuations at a hundred.

With yellow the lowest point reached was fifty per cent. With this exception during the test with this color the curve remained at one hundred.

The average with orange was also high. The lowest point reached was sixty-three per cent.; there were several at seventy-three, one at eighty and the remainder at one hundred per cent.

Violet fell on several occasions to sixty-seven per cent. Otherwise the curve stood at one hundred.

Red-orange showed no failures, but red-red-orange fell once to fifty per cent. The next lowest point recorded was sixty-seven. For the remainder of the time the curve fluctuated between eighty-three and one hundred per cent.

With red No. 2 there were wide fluctuations. At one time the curve fell to forty per cent. and again to forty-five. There was, however, one day at seventy-five and several days at one hundred.

The lowest point reached with all the boxes was eighteen per cent., the highest was one hundred. Between these extremes the curve fluctuated from forty-seven to eighty per cent.

The summary of averages and mean variations by both methods follows:

	Av. 1.	M. V.	Av. 2.	M. V.
Green	67.7	12.6	79.6	18.2
Blue	79.6	18.4	85.3	12.9
Yellow	87.9	13.7	97.6	4.6
Orange	82.8	14.7	91.0	11.9
Violet	85.3	13.4	92.4	11.6
Red-orange	87.0	13.0	100.0	0.0
Red-red-orange	77.0	11.8	87.6	13.8
Red No. 2	54.8	15.7	84.2	22.7
All	64.2	16.8	65.3	16.4
Average	76.3	14.4	87.0	12.3

(*c*) *Dog No. 3.*—This animal showed less decision than the two previously tested. He often spent much time in running from one box to the other with many sniffings, but with only an occasional attempt to actually open either box. This lack of purpose is largely to be accounted for by the fact that, unlike the other animals, he was permitted entire freedom and was not so hungry on most occasions as were the other animals. There is a marked difference shown between the two curves plotted for the trials of this animal.

This animal was tested with the colors introduced in the following order: gray, green, blue, yellow, orange, violet, red-orange, red-red-orange and red No. 2, followed by all the boxes. The results showed less success in the case of this animal than with the first two dogs, especially when plotted by the first method.

The curve plotted by the first method showed comparatively little discrimination for either gray or green, the first two test stimuli introduced. However, twice during the test for the former the curve reached one hundred per cent. It fell below expectancy, however, on several occasions, going as low as zero. For the majority of the tests it fluctuated between fifty per cent. and eighty-seven.

With green the highest point reached was eighty-seven per cent. Once it fell to zero, and on three occasions registered fifty per cent. It varied then from fifty-eight to eighty-one per cent.

The tests with blue gave more satisfactory results. On four occasions the curve reached one hundred per cent., while twice it sank as low as fifty. For the remainder of the time it varied between fifty-seven and eighty-nine per cent.

The test with yellow was somewhat less satisfactory. Although the curve never fell below expectancy during the time that this color was used, it reached fifty per cent. on six occasions. The highest point reached was eighty-nine per cent.

Orange brought the curve down on the first day from eighty-four to fifty per cent. On the third day it sank to twenty-five per cent. During most of the test it fluctuated between fifty-seven and eighty-six per cent.

The results with violet were negative, the curve falling below expectancy on three occasions, and maintaining a low level throughout.

On the introduction of red-orange there was a decided rise in the curve. Only on one occasion did it fall below expectancy, and only once again did it reach as low as fifty per cent. It stood twice at one hundred, and for a considerable part of the time fluctuated between sixty-seven and eighty-seven per cent.

Red-red-orange showed negative results and red No. 2 was but slightly better discriminated, the curve for this color varying from sixty-seven to thirty-five per cent.

Red was fairly well discriminated from all the colors when they were introduced together, the average being decidedly above expectancy.

The curve plotted by the second method showed little ability to discriminate during the first eight days of trial. After this, the curve rose above expectancy on three occasions, reaching one hundred per cent., and the remainder of the time during the test with gray, fluctuated between sixty-seven and eighty-one per cent. The test with green showed better color discrimination, the lowest record being fifty per cent., on the first day. During the remainder of the experiment with this color the curve was between sixty and eighty-eight per cent., except on three occasions when it reached one hundred. The discrimination for blue was relatively high; on eleven occasions the curve reached one hundred per cent., and fell to fifty only once; the remainder of the test it varied from sixty to eighty-nine per cent. The introduction of yellow caused the curve to fall from one hundred to fifty-nine per cent. Twice during this part of the test it fell to fifty per cent.; on the other hand, on nine days it reached one hundred per cent. The remainder of the time it varied from sixty to ninety per cent.

The introduction of orange showed a rise to one hundred per cent. The curve, during this test, was high, except for one day when it fell to zero. On nine days it stood at one hundred. The next highest point was eighty-six per cent., the lowest with the exception of the fall to zero was seventy-one per cent.

The results with violet were for some reason practically negative. On two occasions the curve reached zero, and once again it fell as low as twenty-five per cent. Only on two days did it reach the hundred mark.

Red-orange, on the other hand, shows a very clear discrimination. On seventeen days the curve stood at one hundred. Once it fell to zero, however. The remainder of the test it varied between fifty and sixty-seven per cent.

The test with red-red-orange was equally satisfactory. On eight days it was at one hundred, while the lowest point reached was eighty per cent.

Red just observably different was fairly well discriminated. On one occasion the curve sank to forty per cent., on another to fifty. With these two exceptions it was well above expectancy, standing at one hundred on three days.

Upon the introduction of all the boxes the curve fell from one hundred per cent. to sixty, then to fifty. Later it went up to one hundred where it was found on two occasions. Once, however, it sank to zero. The next lowest was at expectancy, or ten per cent. For the remainder of the test it varied between fifty and seventy-five per cent. The averages for both methods follow:

	Av. I.	M. V.	Av. II.	M. V.
Gray	64.5	20.2	74.8	3.9
Green	62.2	15.6	80.7	13.6
Blue	76.3	12.7	89.5	12.3
Yellow	59.2	12.4	85.0	16.5
Orange	62.0	16.8	86.0	11.1
Violet	48.2	9.3	51.7	8.9
Red-orange	70.3	11.9	89.7	10.9
Red-red-orange	44.7	28.6	97.5	17.5
Red No. 2	53.0	7.0	74.1	18.6
All	58.6	29.1	59.2	28.7
Average	59.9	16.4	78.8	14.2

(*d*) *The Kitten.*—The kitten was tested with the colors in the same order as that presented to dog No. 3.

After the first week of tests the gray was clearly discriminated. The curve plotted by the first method stood on eight days at one hundred per cent. On one occasion, however, it fell as low as twenty-five per cent., on another to forty-five.

For the most part, however, it fluctuated between fifty-five and seventy-five per cent.

Green reached fifty per cent. but once and never went below that point. On the other hand, however, it rose to one hundred per cent. but twice during the entire experiment with this color.

Blue was on the whole higher, reaching one hundred six times. Once, however, it fell to forty per cent. During a considerable part of the time it fluctuated between sixty and eighty-five per cent.

The discrimination for yellow proved to be more successful than for any of the previous colors presented. On fourteen occasions the curve was found at one hundred per cent. Twice it fell to fifty, while the remainder of the time it varied between sixty-three and eighty per cent.

Orange showed a relatively high average, standing at one hundred per cent. during slightly more than half the test. Once, however, it fell to fifty per cent. The next lowest point was seventy-five per cent.

The test for violet gave less favorable results. The highest point reached by the curve was eighty per cent. The lowest was thirty-eight per cent. On two occasions the curve stood at fifty per cent., and the remainder of the test found it between fifty-seven and seventy-five per cent.

Red-orange gave higher average results. The curve on one occasion reached one hundred per cent. The next highest point was eighty per cent.; the lowest was seventy-seven per cent.

During the test with red-red-orange, the curve varied between forty-five and seventy-eight per cent. For about half the tests it was either at fifty per cent. or slightly above or below.

With the red No. 2 the curve was similar to that for red-red-orange. Once, however, it rose to one hundred per cent. The lowest point reached was forty per cent.

The introduction of all the boxes resulted in total failure on the first day of the test. During the rest of the time the curve stood above expectancy. For nearly half the tests it stood at one hundred.

The results of the tests of the kitten as tabulated by the second method show a considerably higher average throughout. Only on four occasions during the entire test did the curve fall below expectancy, once in the case of the gray, once with red, once with green and once when all the boxes were presented. The results with the gray were satisfactory throughout. On sixteen days the curve stood at one hundred, and only on one day did it fall below sixty-eight per cent.

Sixty per cent. of the tests with green resulted in a perfect discrimination. On one occasion, as previously stated, the curve fell to zero. The next lowest point was sixty per cent.

Seventy-five per cent. of the tests with blue found the curve at one hundred per cent. The lowest point reached in this test was sixty-eight per cent.

For yellow the number of perfectly successful tests was still higher, being eighty-one per cent. of the total number. Once the curve fell to expectancy. The next lowest point reached was eighty per cent.

Orange was without a failure, but violet showed a decided drop, although the lowest point reached during the tests with this color was sixty per cent. Approximately one third of the tests with this color were completely successful.

Red-orange was almost perfectly discriminated. Only once did the curve fall below one hundred per cent.

The tests with red-red-orange showed a slight fall in the averages, although the curve never fell below expectancy. It stood on one day at fifty per cent. The next lowest point was seventy-two per cent. In more than two thirds of the trials a perfect discrimination was shown.

On the introduction of the red just observably different the curve fell from one hundred to forty per cent. It then gradually mounted until it reached one hundred per cent. It then fell to eighty per cent. but rose once more to a hundred. On the last two days of the test it fell again and reached thirty-three per cent.

On the introduction of all the boxes it fell to zero, and then rapidly recovered, reaching one hundred per cent. where it remained throughout the test.

The averages of the results of the tests tabulated by both methods together with the mean variation are as follows:

	Av. 1.	M. V. 1.	Av. 2.	N. V. 2.
Gray	69.2	18.2	87.8	15.6
Green	69.9	11.6	82.3	15.0
Blue	79.3	20.3	92.2	11.4
Yellow	86.6	15.0	91.6	9.4
Orange	83.0	17.0	100.0	0.0
Violet	59.4	12.0	81.4	15.9
Red-orange	76.1	7.0	98.3	3.0
Red-red-orange	54.7	8.5	90.1	12.0
Red No. 2	58.4	12.4	65.0	18.2
All	63.8	24.7	65.0	21.2
Average	70.0	14.7	85.4	12.2

(*e*) *The Squirrel.*—The tests with the squirrel were begun somewhat later than those with the other animals, and covered a period of twenty-two weeks, exclusive of a break of one month during which the tests were suspended. The animal soon learned to discriminate with fair accuracy gray from the standard red, the curve fluctuating between expectancy and eighty per cent.

The test with blue showed increasing ability in discrimination. The highest point reached was one hundred per cent. on two days. The curve was found at expectancy on three days. The remainder of the tests resulted in a variation of discrimination between fifty-four and ninety per cent. Once during the test with this color the squirrel made no attempt to open the box and a break in the curve resulted. In subsequent tests this failure to respond was often to be noted, and there were a considerable number of breaks in the curve for this reason.

The introduction of yellow caused the curve to fall from one hundred to fifty-five. It then rose to sixty-five and fell to forty-five. A recovery followed, and then another fall from one hundred to forty-five, followed by a subsequent rise to one hundred and a fluctuation during the remainder of the test between that point and sixty-five per cent.

On the introduction of green the curve again fell, from one hundred to sixty-two per cent. A slight rise then followed

and a subsequent fall to twenty-three per cent. Then came a rise to sixty-three followed by a slight fall and a break.

When the orange box was substituted for the green the curve mounted to one hundred. There it remained for three days and later fell to expectancy. A recovery to the highest point soon followed. The remainder of the test showed the curve relatively high, the lowest point reached being sixty per cent.

The introduction of violet was followed by a rise to one hundred per cent., and then a fall to sixty, the lowest point reached until the last day of the test for this color, when the curve was found at fifty per cent.

Red-orange furnished a series of high averages. The lowest point reached being seventy-five per cent., the highest one hundred. One break was found in the curve during the test with this color.

The red-red-orange brought the curve down to sixty-two per cent.; it then rose to seventy-eight per cent., but soon fell to expectancy. For some days it varied between expectancy and eighty-four per cent. It then sank to forty-six per cent., recovered again, but some days later fell to twenty-five per cent. Later there was a break, after which it rose to one hundred per cent. It soon fell again to fifty per cent., and then for some days maintained a relatively high average, reaching one hundred per cent. on several occasions. The break of one month resulted in a material lowering of the curve. It soon fell to zero, then recovered and fell again to the same point. The next lowest point reached was twenty-five per cent. During the last few days of the test it stood at one hundred per cent.

On the introduction of red No. 2 the curve fell to expectancy. It recovered; then sank to zero. It subsequently rose to one hundred and during the remainder of the test never fell below sixty-six. During the last five days of the test the curve stood at one hundred.

Tabulation by the second method shows a much higher average of discrimination. This was not so striking with the gray as with the subsequent tests. With blue the curve fell

no lower than sixty per cent. For the great majority of the tests the discrimination was perfect, and for over two weeks during the latter part of the test with this color the curve was constantly at one hundred. During the first week with the tests with yellow the curve ran low. Later it reached one hundred, where it remained until the end of the test, except on one day when it fell to sixty-four per cent.

For green the average was very much higher by the second method, the lowest point recorded being eighty-six per cent. For much of the time the curve stood at one hundred.

For orange the curve ran equally high, also for violet and for red-orange.

The introduction of red-red-orange brought a lowering of the curve to eighty; then after several days of entirely successful discriminations there was a fall to sixty per cent. Then, except for an occasional drop, the curve remained for many successive trials at one hundred. The break of one month resulted in an immediate fall of the curve to forty-two per cent., and a later fall to twenty-five per cent., followed by an ultimate rise to one hundred per cent. where it remained for some days.

Red No. 2 caused a fall to expectancy, where it remained for several days. It soon recovered, however, and during the last days of the test stood at one hundred per cent.

The table of averages for each color tabulated by both methods follows:

	Av. I.	M. V.	Av. II.	M. V.
Gray	67.0	12.4	81.3	3.5
Blue	72.2	11.6	98.4	2.1
Yellow	79.5	16.5	91.9	13.0
Green	65.8	11.6	99.0	1.9
Orange	85.8	14.9	99.1	1.7
Violet	75.9	10.7	97.5	3.6
Red-orange	87.0	12.1	98.9	1.9
Red-red-orange	78.9[5]	16.8	90.8[5]	13.2
Red No. 2	(56.6)[6]	(22.3)	(61.1)[6]	(15.7)
Total	65.6	21.8	69.6	15.0
Average	75.3	14.3	91.8	6.2

[5] Before break.

[6] After break, not averaged with other results.

2. *Experiment II.*

A second series of tests were made with dog No. 2 in which blue, yellow and green were used as standards, and the various colors were introduced for comparison. This experiment was brief, occupying but nine weeks. The results show that yellow was most successfully differentiated from these three standard colors. After preliminary tests no failures were made with this color as a standard. The results with blue and green were identical, the average for each color when used as a standard being ninety per cent.

3. *Experiment III.*

In this experiment, as has been previously stated, the attempt was made to determine whether the animals had the power to associate the standard red with the procuring of food under various novel conditions. The aim, in other words, was to discover whether the animal could abstract the color from the receptacle with which he had experienced it in the first series of tests, and recognize its meaning when it was presented to him on receptacles of various sizes and shapes and under diverse circumstances. The three dogs and the kitten were submitted to this test.

The tests with all these animals with the exception of dog No. 2 were relatively brief. Dog No. 1 was tested for fifty-four days and the kitten for seventy days. The tests with dog No. 2 covered a period of one hundred and seventeen days, exclusive of a break in the latter part of the experiment of twenty-three days during which time these tests were discontinued.

In the case of the first three animals tested in this manner, pans, boxes and receptacles of varying shapes were introduced with the stimulus color painted on them; and other receptacles of diverse forms and colors were likewise presented. The combination was varied from day to day, so that no association based on general form could be set up. Typical receptacles thus used are described below:

A red rectangular box 7⅝ x 6¼ x 5¼ inches, with a lid which the animals could easily knock off.

An ordinary cuspidor painted blue, 3½ inches high and 7 inches in diameter, inverted upon a blue platform.

A red oval pan 10¼ inches longest and 7¾ inches shortest diameter; the top of this pan was pierced with holes and it was inverted on a platform used in the experiments with the kitten.

A red strainer used in kitchen sinks, which was inverted over a red platform; this strainer was, when inverted, 4½ inches high at the highest point, with a rounded front incline.

An ordinary milk strainer painted red, 2⅞ inches high, 8 inches in longest diameter at the bottom when inverted over a red platform, and 4 inches across the top.

A red triangular box 4½ inches high, 4½ inches deep and 8½ inches long at the base, resting upon a red platform; this box was tightly closed at the back and across the front was a door extending to within an inch of the apex of the box; this door would fall when attacked by the animals and the whole contrivance could be pushed aside and food secured.

A red box 5 inches wide and 1¾ inches deep, of general rectangular shape but with one end extended into a triangle; one side of this rectangle was 9½ inches long, the other was 8¼ inches and the box at the apex of the triangle was 11½ inches long.

A red box, consisting of two rectangles joined at right angles and communicating into each other. This box was 3½ inches high; the rectangles were 10½ inches in length upon the longer side, and 9½ inches respectively upon the shorter side. This box was fitted with a lid which could easily be knocked off.

A red box with lid in the shape of a triangle, 8½ x 7½ x 8½.

A red cup inverted upon a red platform.

A red box, generally rectangular in shape, but with a square gable placed in the center of the rectangle and communicating with it. This box was 9 inches long, 2½ inches wide and 3 inches high except the middle portion which was 5 inches high.

A long rectangular box painted red, 11½ inches long, 3 inches wide and 1¾ inches deep. This box had a lid which could be easily knocked off and food secured.

A red pan 2 inches high and 8 inches in diameter, notched irregularly and with a hole 1 3/4 inches in diameter in the center of it. When this receptacle was used with the dogs a small red wooden block covered this hole; when the apparatus was used with the kitten, this block was wanting.

During the latter part of the more extended experiments with dog No. 2 the conditions were made more complex. The animals were tested at times with boxes painted with gray or other colors and with only a stripe or circle or cross of the stimulus red; again a red flag of the stimulus color was attached to various receptacles, and on several occasions a red cloth thrown over the food was used as a test. The results in every instance were calculated by the second method, trials being counted only when the animal made a clear attempt to open one of the receptacles, chance sniffings and wanderings being ignored.

A description of the results of these experiments with the various animals follows:

Dog No. 1.—For the first thirteen days of the tests with this animal little discrimination was shown, the average being 65.2 per cent. of correct trials. During the remainder of the test, the curve fell below one hundred per cent. only on six occasions, five of these times reaching fifty per cent. and once thirty-three per cent. During the last ten days of this series not a failure was recorded.

The tests with dog No. 3 were not satisfactory from the fact that it proved even more difficult than in the first series to get reactions of any sort from this animal. During the twenty-four days of this test the animal failed to respond at all on ten. Although he showed evidences of discrimination when reactions were secured, the results were too irregular and trials with him were discontinued.

The kitten learned with much more difficulty to react successfully to this set of test than did dog No. 1. For the first forty-six days out of the total of seventy, the curve shows only a fair degree of discrimination, the average being 74.6 per cent. For the remainder of the series the results are much better. There were several days on which the animal made no at-

tempt, but otherwise the results were uniformly high, there being only one failure recorded, when the curve fell to expectancy. During the last week not a failure was recorded.

It is evident from these results that both dog No. 1 and the kitten learned to make the rudimentary abstractions required to correctly perform the test.

Dog No. 2.—During the first part of the period the animal was given the more simple tests, similar to those used with dog No. 1 and with the kitten; during the last thirty-one days he was tested under more difficult conditions. As before stated during this latter part of the test he was required to distinguish the standard color when it appeared only as a band of color, or as a cross or a flag attached to a receptacle or as a cloth thrown over the food, or under similar complex conditions. His reactions fall into five fairly distinct periods as follows:

For the first eighteen days he was learning to adjust himself to the novel conditions of the test. During this time the curve fell below expectancy on seven days. The average for this period was 58.7 per cent. of correct trials.

For the succeeding sixteen days he had reached a level of very constant perfection. During this time he failed only twice to choose perfectly. His average for this period was 94.7 per cent.

The third period, for the next forty days, showed only one day on which his discriminations were not perfect. On that day for some reason he failed entirely. Otherwise the curve stood uniformly at one hundred per cent.—his average for the entire time being 97.5 per cent.

At this point the experiments were discontinued for twenty-three days, and then resumed. On the first day after this break the dog's reaction showed just fifty per cent. of right choices, but for the following eleven days there were no failures, making the average for these twelve days 95.8 per cent.

The fifth period covers the time of the more complicated experiments. The results for the first eleven days showed a marked falling off from the discrimination of the preceding tests. However, the curve fell below expectancy but once,

when it sank to twenty-five per cent. On three days it was at exactly fifty per cent., giving a total average of 63.3 per cent. The remaining twenty days showed better results. On fourteen of these there were no failures and though the curve fell to fifty per cent. on several occasions it never went below expectancy. The average for this entire period of thirty-one days was 70.7 per cent., showing a clear discrimination though with considerably more failures recorded than during the preceding tests under more simple conditions.

IV. General Conclusions.

1. *Accuracy of Discrimination with Various Colors.*

In considering the results of the first two tests the question arises, whether any of the colors were more accurately and uniformly discriminated from the standard red than were others, and if so what was the basis of this discrimination. Theoretically two opposing possibilities seem open, namely: (1) In associating red with the obtaining of food the animal might practically ignore the other colors presented, and thus not discriminate between them and the stimulus color until they so closely approached the standard as to cause actual confusion, or (2) on the other hand the colors discriminated against might enter clearly into the consciousness of the animal and he then would make successful trials in proportion as their difference from the standard was evident to him. If the first of these alternatives were the correct explanation, we should expect to find that the colors farthest removed from the red would be the ones with which the greatest number of correct choices were to be found. This, however, as the following figures will show, was not the case. The manner of the choice of the various animals should also indicate something in this connection. If the consciousness of the animal were entirely, or for the most part, centered on the stimulus color, to the exclusion of the others it would be likely that in making his choice he would go directly to the proper box, and completely ignore the others. This was not true in the case of the three dogs and the kitten at least, even in successful trials. It often took several minutes of inspection, during which the animal

walked in front of the receptacles, before he actually made an attempt to open one of them and secure the food within. He gave the appearance of actually deliberating or 'making up his mind,' and though no elaborate process of comparison should be attributed to his consciousness at this time, yet all his actions indicated that the color opposed to the stimulus red was sufficiently an element of consciousness to make the choice of the proper receptacle difficult until the proper color discrimination had been made. With the squirrel there appeared to be less of this seeming deliberation than with the other animals tested. Further, if the color to be discriminated against entered clearly into the perception of the animal it would be expected that on the introduction of that color for the first time the curve would tend temporarily to fall. This was the case in general. In seventy per cent. of all the tests there is such a fall. In one per cent. there is neither rise nor fall and in twenty-nine per cent. a rise which, however, is in almost every instance soon followed by a fall below the general level at which the curve stood at the end of the test with the preceding color. As a rule the first few days of the trials with a newly introduced color show less accuracy of discrimination than do the succeeding days of trial with that color. The following table gives the relative success of each animal in discriminating the stimulus color from the others.

Table Giving General Summary of Results.

(Figures at right of column indicate per cents by first method, figures at left per cents by second.)

	Green.	Blue.	Yellow.	Orange.
Dog 1	84.9–89.0	93.1–100.0	84.4–91.0	77.5– 98.3
Dog 2	67.7–79.6	79.6– 85.3	87.9–97.6	82.8– 91.0
Dog 3	62.2–80.7	76.3– 89.5	59.2–85.0	62.0– 86.0
Kitten	69.9–82.3	79.3– 92.2	86.6–91.6	83.0–100.0
Squirrel	65.8–99.0	72.2– 98.4	79.5–91.9	85.8– 99.1
Average	70.1–86.1	80.1– 93.1	79.5–91.4	78.2– 94.9

	Violet.	Red Or.	R. R. Or.	Red 2.
Dog 1	87.8–97.2	91.4–100.0	93.4–98.4	64.4– 81.3
Dog 2	85.3–92.4	87.0–100.0	77.0–87.6	54.8– 84.2
Dog 3	48.2–51.7	70.3– 89.7	44.7–97.5	53.0– 74.1
Kitten	59.4–81.4	76.1– 98.3	54.7–90.1	58.4– 65.0
Squirrel	75.9–97.5	87.0– 98.9	78.9–90.8	65.6– 69.6
Average	71.3–84.0	82.3– 97.4	69.7–92.9	59.2– 74.8

In the case of dog No. 1 the color having the highest average of correct choices, according to the first method of tabulation, is red-red-orange. The other colors follow in the order named—blue, red-orange, violet, green, yellow, orange and red No. 2. According to the second method of tabulation the order is, red-orange and blue (both at one hundred per cent.), red-red-orange, orange, violet, yellow, green and red No. 2. Although no pronounced color preference is here indicated there seems to be a tendency toward the red-oranges and the blue and away from the green and the yellow.

With dog No. 2, the table, according to the first method of calculation, shows a preference for yellow, with red-orange second, and the remaining colors in the following order, namely —violet, orange, blue, red-red-orange, green and red No. 2. The results according to the second method of tabulation are—red-orange, yellow, violet, orange, red-red-orange, blue, red No. 2 and green. This animal shows a preference for the orange, the yellow and the red-orange as against blue and green.

Dog No. 3 reacted most accurately to red when contrasted with blue, according to the first method of tabulation. The color next highest is red-orange, then green, orange, yellow, red No. 2, violet and red-red-orange. The second method gives the order as follows: red-red-orange, red-orange, blue, orange, yellow, green, red No. 2, violet. This indicates a clearer discrimination for blue and the red-oranges.

The order of discrimination for the kitten by the first method is—yellow, orange, blue, red-orange, green, violet, red No. 2, red-red-orange; by the second method—orange, red-orange, blue, yellow, red-red-orange, green, violet, red No. 2. Here a preference is indicated for yellow the red-oranges and blue.

The order for the squirrel is, by the first method—red-orange, orange, yellow, red-red-orange, violet, blue, green, red No. 2; by the second method—orange, green, red-orange, blue, violet, yellow, red-red-orange, red No. 2. The oranges on the whole seem to stand highest.

An average of the results for all the animals gives the order tabulated by the first method as follows: red-orange, blue,

yellow, orange, violet, green, red-red-orange, red No. 2; by the second method the order is—red-orange, orange, blue, red-red-orange, yellow, green, violet, red No. 2.

Summarizing these results in another way it may be seen that the colors standing highest were as follows: red-orange (3), blue (2), yellow (2), orange (2), red-red-orange (2). The two lowest colors were violet (2) and green (4). From this comparison red No. 2 is omitted because of the fact that its nearness to the standard made accurate discrimination difficult, it being the lowest color in six instances, green standing below red No. 2 twice, and violet twice.

By glancing at the above table it will be further seen that the colors averaging above ninety according to the first method of tabulation were: blue (1), red-orange (1), red-red-orange (1); according to the second method—yellow (4), orange (4), red-orange (4), red-red-orange (4), blue (3), violet (3), green (1). The colors averaging below seventy according to the first method of tabulation were—red No. 2 (5), green (4), violet (2), red-red-orange (2), yellow (1), orange (1); according to the second method—red No. 2 (3), violet (1).

The above facts taken together do not show any pronounced discrimination in favor of one color. On the whole the various oranges and the blue stand the highest, while the violet and the green, together with red No. 2, occupy the opposite end of the scale.

It should, however, be noted in this connection that the temporal order of green, since it came early in the series, may have had something to do with the lower record made with this color than with those coming later. This is particularly true in the tests with dog No. 2, in whose case, because of the exigencies of the experiment, green was introduced before he had clearly learned the proper reaction to the stimulus color with gray. For this reason, probably, green should be placed somewhat higher in the series, perhaps above violet.

These results seem quite the reverse of those that Rouse found to be true of his pigeons. With them the finest discrimination was with green and the lowest with blue. Kinne-

man found that with his monkeys blue was discriminated against. The results are more in line with the tests made in color discrimination in children, although Preyer places blue last with green next. Binet's order as previously stated is red, blue, orange, rose violet, green, yellow. Baldwin's tests placed blue first with green next to the last, and higher than brown; while Nagel places green, violet and red on an equal footing and assigns to blue the lowest place in the list.

Rivers (47) in an investigation of the vision of the natives of the Torres Straits has made an extensive study of their color vision. Among other things he concludes that the "color vision of the Papuan is characterized by a certain degree of insensitiveness to blue (and probably green) as compared with that of Europeans." His reasons for this conclusion are: (1) The races examined had either no word for blue or an indefinite one. Blue is probably for them a darker and duller color than for us. (2) The Holmgren test showed that blue and green were constantly confused. (3) Observations with the tintometer showed that "the Murray Island natives distinguished red when very faint, much more readily than blue." Rivers found that the savages tested by him showed a much finer sensibility for red than do Europeans. The investigator adds that this lack of discrimination for blue is in line with the fact that "in ancient literature, as among modern barbarous and savage races, it is the color blue for which nomenclature is especially defective. . . . The color vision of the Torres Straits islander gives some support to the views of Gladstone, Geiger and Magnus that the defective color language of ancient literature may have been associated with a defective color sense."

Investigations by Seligmann[7] reported in an appendix to the study of Rivers, on the vision of natives of British New Guinea show confusion and uncertainty in color nomenclature, particularly in regard to blue, green, indigo, violet and black. Later investigations by Rivers point to the same conclusions

[7] C. G. Seligmann, 'Cambridge Anthropological Expedition to the Torres Straits,' Vol. II., Pt. I.

as his earlier experiments. The lack of discrimination for blue shown in these anthropological studies finds no parallel in the tests of the present experiment.

2. *Fineness of Color Discrimination.*

The tests seem clearly to show a surprising fineness of color discrimination among the animals tested. The averages show that the red-orange was more successfully discriminated from the standard red than was the blue, yellow, green and violet, although the red-orange is nearer in quality to the standard than any of these. Even red-red-orange, according to the second method of tabulation, stands above yellow, violet and green and is practically on a par with blue. It is only when the red which is barely observably different from the standard is introduced that there is a marked lowering of the curve. Even here the successful attempts (according to the second method of tabulation) are three fourths of the whole.

3. *Memory for Color of the Animals Tested.*

Incidentally in the course of the experiment two of the animals, namely, dog No. 2 and the squirrel were tested for their ability to remember the standard color after some little time had elapsed since they were last tested with it. These memory tests were not originally planned, but were made merely because of the exigencies of the experiment. The course of the experiment, as previously stated, was suspended for three weeks in the case of dog No. 3 and practically no loss of memory for the standard color was shown.

Doubtless a much longer period might have elapsed without substantial loss—in the case of the squirrel the effect was different. After one month's suspension of the trials with red-red-orange the experiment with the squirrel showed for the first few days after renewal of the tests practically no discrimination. Although the results later were somewhat better the animal showed for a considerable time the effect of the suspension of the tests.

4. *Ability to Form Abstract Notions in Regard to Color.*

The most significant part of the experiment with the various animals was that which was conducted under the third series of tests, since the results here seem to point to a somewhat higher mental capacity among the animals than that ordinarily assigned to them. There has been considerable discussion in recent years as to the power of animals to abstract from the flow of their concrete experience any elements which shall be of general significance in the guidance of their conduct. Thorndike in particular feels sure that animals do not have the power to form 'free ideas,' as he terms them. Their acts are due to simple associations learned in a definite series; and they show no ability of applying the data of past experiences to novel situations. On the other hand, we find some writers on animal intelligence who attribute much higher mental powers to brutes. Ramsey (45) asserts that under a sufficient stimulus dogs may use inferential associations. Ament (3) reports the behavior of a two-year-old dog, who on a cold day found a window from which he was accustomed to look so coated with frost that his view was obstructed. Thereupon the dog licked away an area about the size of a plate, and then stopped, looking through the cleaned glass and observing the cats in a neighboring yard. The author concludes that here we have a case of genuine '*Ueberlegung*.' It is hardly necessary to observe that since this reported case was merely the matter of casual observation and since the situation was in no way put under experimental control, it deserves scarcely more notice than that of hundreds of cases of fabulous powers of animals reported by uncritical observers. One would indeed be rash to assert that dogs possess any degree of rational power without better evidence than that offered by Ament, although his paper appears in a journal of high scientific standing.

Opposed to such conclusions as these, but with no more scientific basis for the assertion of an opinion, is Hill, who denies any power of symbolic thought in dogs. More careful investigators and observers of animal intelligence like Morgan (37) and Mills (36), while unwilling to accept extravagant

views of the mental powers of brutes, still are not quite as conservative in their opinions as is Thorndike.

Recently Cole (10), reporting an investigation concerning the intelligence of raccoons, says:

"In concluding the description of experiments in discriminating cards of different colors and intensities, I pointed out that successful reactions demand that the raccoon compare a color which has just *disappeared* with one now present. Either this or else the animal must keep track of the number of times the colors are shown, going up every other time when the colors appear alterately, every third and fourth time when they appear by twos, etc. This second explanation violates the law of parsimony, of course, and was eliminated by the fact that I secured series of perfect reactions when the colors were shown at random. When I changed for the first time from alternate showing to twos, or from twos to threes, there resulted confusion and errors quite sufficient, I think, to show that the animals distinguish one movement from two or two from three (a species of counting). As this was of no avail when the colors were shown at random, I also believe that the animal must have retained some sort of image or visual impression of the absent color and reacted to it."

It seems reasonable from the results of the present experiment to hold a middle ground and conclude that the dogs and the other animals tested did succeed in arriving at the notion that a certain color, merely as color and apart from any particular setting functioned practically for food. Of course, it is not necessary to assume that such a notion was ever raised into clear consciousness, nor that the animals had a definite recognition of it. Still they did show ability to apply their previous experience to new conditions. This, however. they did not do, it is to be observed, on their own initiative, but only when the color had been abstracted for them, so to speak. When the test of Experiment III was first presented to dog No. 2, for example, he showed no ability to react successfully to it; but after over two weeks of trial, he learned to divorce the color from its particular situation and apparently to understand that it stood in general for food. His reactions were then in nearly

every trial correct, until, during the fifth period, the conditions were increased in complexity and a confusion at first resulted which caused a temporary falling of the curve, which, however, later recovered.

The significance of these results in relation to the rational powers of animals of the degree of intelligence of those tested in the experiment is that apparently they possess no initiative in the direction of abstraction, but on the other hand that they can be taught a rudimentary abstraction if conditions are artificially arranged by the experimenter; and so under very special conditions they may show an ability to develop 'free ideas' of a low grade, which ability appears, however, to be lacking under the more ordinary conditions in which the animal is placed.

V. Bibliography.

1. Adams, G. P. On the Negative and Positive Phototropism of the Earth Worm, *Allolobophora fœtida* (Sav.), as Determined by Light of Different Intensities. *Amer. Jour. of Phys.*, IX., 26–35 (1903).

3. Allen, Grant. The Color Sense. Second edition. London, 1892.

3. Ament, Wilhelm. Ein Fall von Ueberlegung beim Hund? *Arch. f. d. ges. Psychol.*, VI., 249–253 (1905).

4. Axenfeld, D. Die Röntgen'schen Strahlen dem Insectenauge sichtbar. *Centralb. f. Phys.*, X., 436–437 (1896).

5. Baldwin, J. M. Mental Development. Third edition. New York, 1906.

6. Bert, P. Sur la question de savoir si tous les animaux voient les mêmes rayons lumineux que nous? *Arch. de Physiol.*, II. (1869).

7. —— Influence de la lumière verte sur la sensitive. *Comptes Rendus*, LXX., 338–340 (1870).

8. Binet, A. Perceptions d' enfants. *Revue Philosophique*, XXX., p. 584 (1890).

9. Bohn, G. De l' évolution des connaissances chez les animaux marins littoraux. *Bulletin Institut gén. Psychol.*, No. 6 (1903).

10. Cole, L. W. Concerning the Intelligence of Raccoons. *Jour. of Comp. Neurology and Psychology*, XVII., No. 3 (1907).

11. DAVENPORT, C. B. Experimental Morphology. New York (1897–1899).

12. ENGELMANN, T. W. Ueber Reizung des contraktilen Protoplasmas durch plötzliche Beleuchtung. *Arch. f. d. ges. Physiol.*, XIX., 1–7 (1879).

13. —— Ueber Licht- und Farbenperception niederster Organismen. *Ibid.*, XXIX., 387–400 (1882).

14. —— *Bacterium photometricum. Ibid.*, XXX., 95–124 (1883).

15. FATIGATI, E. S. Influences des diverses couleurs sur le développement et la respiration des infusoires. *Comptes Rendus*, LXXXIX., 959–960 (1879).

16. GARNER, R. L. The Speech of Monkeys. New York, 1892.

17. GATES, ELMER. The Science of Mentation. *Monist*, V., 574–597 (1895).

18. GRABER, VITUS. Grundlinien zur Erforschung des Helligkeits- und Farbensinnes der Thiere. Prag, 1884.

19. —— Fundamentalversuche über die Helligkeits- und Farbenempfindlichkeit augenloser und geblindeter Thiere. *Sitzb. der k. Akad. der Wissensch.*, Wien, LXXXVII. (1883).

20. —— Ueber die Helligkeits- und Farbenempfindlichkeit einiger Meerthiere. *Ibid.*, XCI. (1885).

21. HARPER, E. H. Reactions to light and mechanical stimulation in the earthworm, *Perichæta bermudensis. Biol. Bulletin*, X., 17–35 (1905).

22. HARRINGTON, N. R., and LEAMING, E. The Reaction of Amœba to Lights of Different Colors. *Amer. Jour. of Physiol.*, III., 9–18 (1899).

23. HERTEL, E. Ueber Beeinflussung des Organismus durch Licht, speziell durch die chemisch wirksamen Strahlen. *Zeitschr. f. allg. Physiol.*, IV., 1–43 (1904).

24. HILL, A. Can Dogs Reason? *Nature*, LXVII., 558–559 (1903).

25. —— *Ibid.*, LXVIII., 7–8 (1903).

26. HIMSTEDT, F., und NAGEL, W. Versuche über die Reizwirkung verschiedener Strahlenarten auf Menchen- und Tieraugen. Festschr. der Albert-Ludwigs-Universität in Freiburg, Freiburg, 1902.

27. HOLMES, S. J. The Reactions of *Ranatra* to Light. *Jour. Comp. Neurol. and Psychol.*, XV., 305–349 (1905).

28. —— The Selection of Random Movements as a Factor in Phototaxis. *Ibid.*, XV., 98–112 (1905).

29. HOLT, E. B., and LEE, F. S. The Theory of Phototactic Response. *Amer. Jour. of Physiol.*, IV., 460–481 (1901).

30. JENNINGS, H. S. Behavior of the Lower Organisms. New York, 1906.
31. KINNEMAN, A. J. Mental Life of two *Macacus rhesus* Monkeys in Captivity. *Amer. Journal of Psych.*, XIII., 98–148, 173–218 (1902).
32. LOEB, J. Der Heliotropismus der Thiere. Wurzburg, 1900. See also Comparative Physiology of the Brain and Comparative Psychology. New York, 1900.
33. LUBBOCK, J. On the Sense of Colors among Some of the Lower Animals. *Nature*, March, 1882, 422–424.
34. —— Ants, Bees and Wasps. New York, 1883.
35. MEREJHKOWSKY, C. DE. Les Crustacés inférieurs distinguent—ils les couleurs? *Comtes Rendus*, XCIII., 1160 (1881).
36. MILLS, T. WESLEY. The Nature and Development of Animal Intelligence. New York, 1898.
37. MORGAN, C. LLOYD. An Introduction to Comparative Psychology. Second edition, London, 1906.
38. NAGEL, W. A. Der Lichtsinn augenloser Thiere. Jena, 1896.
39. —— Observations on the Color Sense of a Child. *Jour. of Comp. Neurol. and Psychol.*, XVI., 217–230 (1906).
40. PARKER, G. H. and ARKIN, L. The Directive Influence of Light on the Earthworm, *Allolobophora fœtida* (Sav). *Amer. Jour. of Phys.*, V., 151–157 (1901).
41. PARKER, G. H., and BURNETT, F. L. The Reactions of Planarians with and without Eyes to Light. *American Jour. Physiol.*, IV., 373 (1900).
42. PECKHAM, G. W., and ELIZABETH, G. The Sense of Sight in Spiders, with Some Observations on the Color Sense. *Trans. Wis. Acad. Sci.*, X. (1894).
43. PORTER, J. P. The Habits, Instincts and Mental Powers of Spiders, Genera *Argiope* and *Epeira*. *Amer. Jour. of Psych.*, XVII., 306–357 (1906).
44. RÁDL, E. Untersuchungen über die Phototropismus der Thiere. Leipzig, 1903.
45. RAMSEY, W. Can Dogs Reason? *Nature*, LXVII., 609 (1903).
46. RIBOT, TH. The Evolution of General Ideas. (Tr.) Chicago, 1899.
47. RIVERS, W. H. R. Reports of the Cambridge Anthropological Expedition to Torres Straits, II., pt. 1 (1901).
48. ROYCE, JOSIAH. Outlines of Psychology. New York, 1903.
49. ROUSE, J. E. The Mental Life of the Domestic Pigeon. Harvard Psych. Studies, II., 581–613 (1906).

50. —— Respiration and Emotion in Pigeons. *Jour. of Comp. Neurol. and Psych.*, XV., 494–513 (1905).
51. SMALL, W. S. Notes on the Psychic Development of the Young White Rat. *Amer. Jour. of Psychol.*, XI., 80–100 (1899).
52. —— Experimental Studies of the Mental Processes of the Rat. *Ibid.*, XI., 133–165 (1900), and XII., 206–239 (1901).
53. SMITH, AMELIA C. The Influence of Temperature, Odors, Light and Contact on the Movements of the Earthworm. *Amer. Jour. Physiol.*, VI., 459–486 (1902).
54. STRASBURGER, E. Die Wirkung des Litchtes und der Wärme auf Schwärmsporen. Jena, 1878.
55. THORNDIKE, E. L. Animal Intelligence. New York, 1898.
56. —— The Mental Life of Monkeys. PSYCH. REV., MONOGRAPH SUPP., IV. (1901).
57. —— The Experimental Method of Studying Animal Intelligence. *Internat. Monthly*, Feb., 1902.
58. TORELLE, ELLEN. The Response of the Frog to Light. *Amer. Jour. of Phys.*, IX., 467–488 (1903).
59. VERWORN, M. Psycho-physiologische Protistenstudien. Experimentelle Untersuchungen. Jena, 1889.
60. —— Allgemeine Physiologie. Jena, 1895.
61. WASHBURN, M. F., and BENTLEY, I. M. The Establishment of an Association Involving Color Discrimination in the Creek Chub, *Semotilus atromaculatus*. *Jour. of Comp. Neurol. and Psychol.*, XVI., 113–125 (1906).
62. WILSON, E. B. The Heliotropism of *Hydra*. *Amer. Naturalist*, XXV., 413–433 (1891).
63. YERKES, R. M. A Study of the Reactions and Reaction Time of the Medusa *Gonionema murbachii* to Photic Stimuli. *Amer. Journ. Physiol.*, IX., 279–307 (1903).
64. —— The Dancing Mouse. New York, 1907.

SOME PRELIMINARY OBSERVATIONS ON THE DEVELOPMENT OF INSTINCTS AND HABITS IN YOUNG BIRDS.[1]

BY F. KUHLMANN.

CONTENTS.

A. General Aim of Study.

The general purpose of this study was to get some observations on the origin of instincts and on the formation of the first associations. All vertebrates, as well as several lower forms, that have been put to the test have been found capable of adjusting their behavior on the basis of some sort of memory of past experience. When we come to make observations on

[1] Two years ago Professor E. C. Sanford suggested to Dr. G. Ordahl that animal infancy might be a promising field of investigation. On further consultation I suggested that birds would offer the best means of approaching this subject. This study of young birds we took up together in the season of 1907, during which Dr. Ordahl did the major part of the observing. Circumstances not permitting him to continue the work, I carried it further during the following season. During the first season Robins, Chipping Sparrows and Rose-breasted Grosbeaks were observed. For the second season the place of observation shifted from Massachusetts to central Nebraska, and the birds studied were the Redwinged Blackbird, the Brown Thrush and the Mourning Dove.

the natural activities of adult animals we are confronted, therefore, with a difficult problem of analysis. This is the problem of the exact relation of instinct and intelligence in any given case. Even such a familiar and much-observed phenomenon as fear in animals is not yet entirely understood as regards the nature of its origin and the type of behavior to which it belongs. The general question involved here cannot be decided by determining the degree of learning capacity, nor by establishing the fact that in certain cases under controlled conditions certain activities are acquired through experience and not inherited through instincts. Where the possibility of both modes of acquisition is given the actual fact as to the relation of these two factors in the various natural activities of animals must be determined by observation on these activities themselves. And the observation must begin before the activities in question are already formed. This takes us to the study of animal infancy, wherever a period of immaturity and development precedes the adult form, for it is during this period that many of these activities begin.

The problem, however, is not so easy of solution as might seem from this statement. This study was begun with the more or less accepted view that instincts, although they may be deferred, never as such show any definite period of development; that each appears more or less abruptly in its final form without any significant change in its character, except as affected by experience. This makes gradual acquisition one of the criteria of the intelligent character of any behavior in question. Our general results, however, show, we believe, that such a view is quite untenable. A given piece of behavior may be gradually acquired in a manner and under conditions that preclude past experience playing a part; an instinct as such may show stages of gradual development. It is obvious that the proof of this suggestion may be difficult to establish. For it is often difficult to make observations so minute and complete as to justify our assuming that nothing of importance in regard to the experience of the animal in question has escaped us. And it is even more difficult to always make certain that we are rightly interpreting the significance of past experience that we

have observed. Wherever such questions as these arise greater thoroughness of observation and control of factors involved alone can decide. It was the original aim to study the origin of instincts and of intelligent behavior in a number of different species in order to get observations on the greater variety of behavior that a number of different species will always show. The results of two seasons with observations on six species have, we believe, justified our efforts on this *general* problem. But certain aspects of the study have inclined me to the view that a more intensive study of one or two species only will in the end prove more profitable. This will at least give us a better and more correct comprehension of the life of the animals studied, in relation to which life alone the meaning of the particular instincts and other types of behavior must be judged. I therefore make the present preliminary report.

B. Method of Study.

The study of the natural activities of animals in their natural environment has always to contend with two difficulties. The first is that of keeping the animals under continuous and prolonged observation; they get out of range of observation, or out of sight in the woods, marshes, or in their burrows. The second is the animals' fear of man. To avoid disturbance the necessary distance between observer and observed is usually too great for much observation.

In the case of the study of young birds both these difficulties have been largely met, at least for altricial species. Since the young of these birds spend nearly the whole period of their development in the nest, they are always accessible to observation if the nest itself is. Herrick's method of getting the nest within close range of observation consisted in removing it together with its immediate supports and fixing it again three to four feet above ground.[2] This, he found, could be done after the young were several days old, without causing the parent birds to desert. He then pitched a small observation tent within a few feet of the nest, and found that usually in the course of an hour or so the parent birds resumed the care and

[2] *Home Life of Wild Birds,* New York, 1905.

feeding of the young in approximately a normal way. In thus eliminating the fear of the parent birds as a disturbing factor the following general facts are made use of. First, the strong instinctive attachment to the young, which increases with the age of the young. Secondly, the parent birds' capacity for learning. The stationary, silent, unchanging, and harmless tent soon ceases to arouse fear.

Our methods of observation were essentially the same as those of Herrick. But since our aim required observation of the young from the time of hatching it is obvious that some variations were necessary. In the first place, we never removed the nest and fixed it again close to the ground. Instead of this a mirror was placed about a foot back of and a little above the nest, hinged so as to reflect the image of the young at any desired angle. The mirror was found usually to cause little or no disturbance. An observation tent was then pitched some distance from the nest, and a field glass used to see the young in the mirror. When necessary, both mirror and tent were at first somewhat removed from the nest and gradually moved closer from day to day, beginning this before the young were hatched. The same was done with a cloth used later to cover a camera, when pictures of the different aspects of the behavior at the nest were desired. The degree of precaution necessary, as Herrick observes, depends on three variable factors: the species, the individual bird and the age of the young.

With these variations from Herrick's procedure, we have been able to keep the young of six different species under continuous observation from the time of hatching until they left the nest, extending the observations for several days after they had left the nest in a few cases. In all, thirty-two nests have been observed, but on only about twenty have the observations been systematic and continuous. In only a few cases were the observations on a nest made continuous throughout the day. In place of this a given nest was observed from one to four hours daily. As already stated, the species studied were the Chipping Sparrow (*Spizella socialis*), the Rose-breasted Grosbeak (*Zamelodia ludoviciana*) and the Robin (*Merula migratoria*) during the first season, and the Redwinged Blackbird

(*Agelaius phœniceus*), the Brown Thrush (*Harporhynchus rufus*) and the Mourning Dove (*Zenaidura macroura*) during the second. The main results will be considered under three headings: (1) Motor development, (2) the food reaction, (3) the development of fear.

C. Motor Development.

I shall use the term 'motor development' to include both growth in weight and strength, and acquisition of motor coördinations. Not considering the factors of health and nutrition so far as these are determined by external environment, the former belongs rather strictly to the realm of heredity. But the relation of heredity and exercise in the acquisition of motor coördinations has in most cases been a debated question. To my mind the question is not one that lends itself at once to a *general* consideration. It must be studied independently for each species. For obviously there is a wide range of relationship between the two factors. So far as our present knowledge goes, the motor coördinations of a large number of species do not improve from the day of birth, while among the vertebrates there are many that show a long period of functional immaturity during which motor coördinations are gradually acquired. We cannot on the one hand say, therefore, that even the highest degree of complexity in motor coördinations without exercise is impossible. On the other hand, we cannot for this reason infer at once as to the unimportance of exercise where the coördinations are gradually acquired.

Aside from this question is the equally fundamental one which concerns the relation of growth and the acquisition of coördinations. Here, too, the range of possibilities from species to species seems to be nearly unlimited. A high degree of immaturity as regards size and weight is in some species correlated with complete or nearly complete motor coördinations, while in others maturity in growth and in function appear nearly simultaneously. Like the former, therefore, this question is also not one for general consideration before the facts for the different species are known better. The facts in regard to both questions have their immediate interest in connection

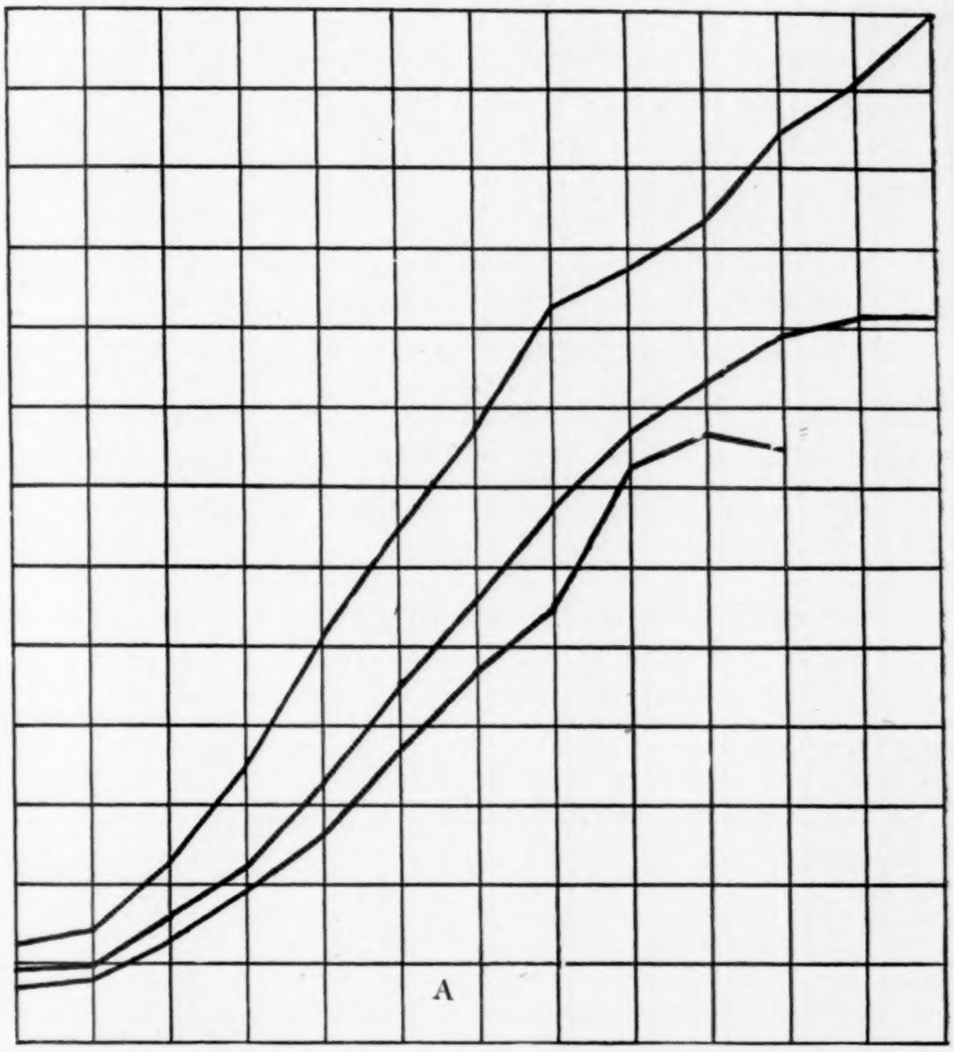
with the individual species. The relation existing between hereditary acquisition and acquisition through exercise, between growth and coördination, for a given species must have some meaning for that species, must in the rough at least be an adaptation for its life and life conditions. It is from this standpoint that we should endeavor first to understand the facts.

In our study an effort was made to get minute observations on the development of motor coördinations as would appear in the movements and activities of the young birds from the time of hatching until they were lost to observation after having left the nest. For the three species observed during the second season the young of a number of nests were also weighed daily, or every other day, in order to determine the nature of their growth curves. I shall give the results on the growth curves first.

1. Growth Curves.—For the nests for which the young were to be weighed observations were begun before the young hatched, to the extent of making at least daily visits. Under these circumstances the age of the young at the first weighing might vary from less than an hour to nearly twenty-four hours. But a bird nearly twenty-four hours old can be recognized as such, and in these cases the first weighing was counted as that of the second day. Birds of the same nest that hatched on different days were marked with different colors to prevent confusion later. The number of birds weighed for the Brown Thrush and the Mourning Dove is not very large, but the results are so regular and agree so completely for the three species that I offer them as trustworthy on the general characteristics that will be considered. No doubt results based on a very much larger number of cases would show minor facts that the present curves do not indicate. The following table gives the average weight in grams from the day of hatching till the birds left the nest. The day on which a bird hatched is in each case counted as the first day. This manner of designating the age will be adhered to throughout. The '0' day then gives the weight of the egg.

Fig. A, Plate I., gives the curves based on the figures in this table, the lowermost being that for the Redwing, and the upper-

PLATE I.



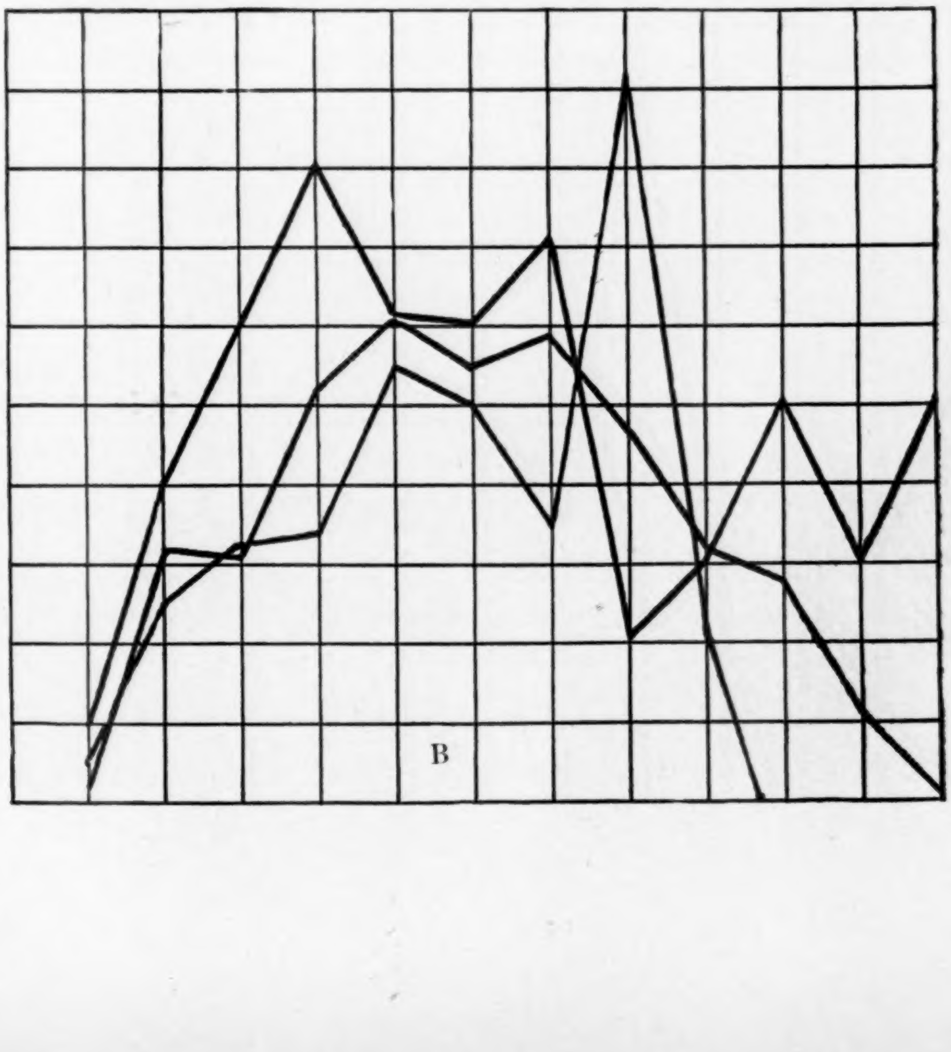


TABLE I.

Days	0	1	2	3	4	5	6	7	8	9	10	11	12
Redwing...	3.5	4.0	6.5	9.7	13.1	18.6	23.6	27.1	36.3	38.5	37.4		
No. Cases..	5	19	23	21	16	17	9	9	6	8	6		
B. Thrush..	4.6	4.8	8.0	11.1	16.3	22.4	27.9	33.8	38.5	41.7	44.5	45.6	45.7
No. Cases..	2	3	3	4	4	6	4	7	7	7	6	4	3
M. Dove ...	6.1	7.1	11.4	17.5	25.7	32.5	38.6	46.2	48.6	51.8	57.2	60.3	65.6
No. Cases..	3	3	4	5	5	5	3	4	4	4	4	4	3

most one that for the Mourning Dove. They show a remarkable degree of regularity, considering the small number of cases. The young of the Redwing were not as healthy as were the others. In a number of cases they stopped growing suddenly, sometimes losing weight, and in a few cases died a day or two later. Cases that stopped growing entirely for a day or more were not counted after this cessation of growth. But the irregularity in the growth curve for the Redwing is probably due to a smaller variation in health than was considered. The Brown Thrushes seemed in every respect to be exceptionally healthy birds. It is seen that their curve is absolutely regular throughout. The curves for these three species agree in three general characteristics. There is in all a slow rise at the beginning. This is followed by a more rapid rise for several days. Thirdly, the last several days in the nest show a decline in the rate of growth.

These characteristics can be seen better in the derived curves, showing directly the rate of growth and changes in the rate. Fig. B, Plate I., gives these derived curves. They are based on the difference in weight between each day and the next. That is, the height of the curve for any day represents the number of grams increase in weight over that of the preceding day. These derived curves show clearly three periods of growth. (*a*) A period of slow but increasing rate of growth, lasting from the first to about the fourth day. (*b*) A period of maximum but constant rate of growth, lasting from about the fourth to the seventh day. (*c*) A period of decreasing rate, beginning about the seventh day.

2. THE ACQUISITION OF MOTOR COÖRDINATIONS.—For the present I shall not distinguish between motor coördination in the strict sense and neuro-muscular strength, but shall regard

the increasing ability to move the limbs and other parts in a coördinated way as a process of acquiring motor coördinations. To trace out the course of this development different nests of the six species mentioned were kept under daily observation under conditions that seemed, so far as we could determine, entirely normal for the birds in question. In this the camera was an important supplement to the note-book, in as much as it furnished illustrations of the normal attitudes of the young at different ages, which could be brought together and compared later in a way that description alone does not make possible. In the following description the ages given for the different periods of development refer mostly to the Redwing. The course of development, however, is exactly the same for the other species, excepting the Mourning Dove in some minor matters. The species observed vary simply as regards the rate of development.

(*a*) *First Stage.*—At the time of hatching the young are nearly inert. The legs and wings project loosely from the body, and during the first day the head and neck are coiled ventrally most of the time. The legs are entirely useless, and play no part in the movements of the body, which is a shapeless mass of pot-belly and head. The movements are mostly incoördinated wrigglings, which are not always sufficient to right the bird if by accident it has been turned onto its side or back. In this event it simply continues its wrigglings until by accident it rolls back again into the normal position. Plate II., 27.1, shows a bird on the second day after hatching, lying on the side and struggling to right itself. (The numbers in this plate and in the following ones give the age of the bird, and the nest and negative numbers. The number under each individual bird gives the age, counting the day of hatching as the first day. In the other the number preceding the decimal point is the nest number, that following the decimal point is the negative number for that nest. The former will serve to indicate whether successive illustrations are of the same individual birds or from different nests.) The only coördinated movement present is the food reaction. This consists of raising the head and neck into a vertical position and a wide gaping of the mouth (Plate

III.). The stubby wings usually assist some from the outset in attempting to brace and raise the anterior part of the body at the same time. This use of the wings continues and increases during the next several days, but without the energy necessary to raise the body very much (Plate III.). By the second or third day the neck and head have become quite uncoiled from their ventral position. The birds now normally lie stretched out flatly, the head and neck lying loosely and limp as did the legs and wings from the first (Plate II., 24.4, Plate III., 18.1). The shape of the body has changed slightly, presenting a wider and flatter ventral surface. They have less difficulty in righting themselves when turned over. The pliant viscera of the pot-belly is beginning to serve as ballast and a foot for keeping the bird in a normal position, which function it fulfills for the next five to six days. By the fifth or sixth day the first stage of acquisition of motor coördinations is completed. The legs are now usually drawn in and folded under the body instead of extending loosely. The head is also pulled in, shortening the previous slender neck in appearance. The wings hang about as before (Plate II., 21.3, 19.2, 6, 7). The food reaction is given with much more vigor, and the wings are used more than at first to brace and raise the body. There is a marked increase in neuro-muscular strength. When arranged in the nest with the heads away from the center, which is a position the young begin to take by this time, the pushing of the wings against the sides of the nest often enables them to raise themselves upon end. In this the legs play no part, but come up in a vertical position with the body, remaining folded against it as in the reclining position. When the birds are taken out of the nest and placed on the smooth surface of a board the legs, if used at all, make only random sprawling movements that do not raise or move the body. In their normal position at rest they are folded in under the body as when the birds are in the nest.

(*b*) *Second Stage.*—From the fifth to the seventh day inclusive there is little or no progress in the motor coördinations. We may call this period, therefore, the second and stationary stage of development. The birds become more active and

vigorous, but otherwise the nature of their movements does not change noticeably.

(*c*) *Third Stage.*—By the seventh to the eighth day this stationary period is broken. From now on rapid progress in motor coördinations is made. I shall call it the third stage, which ends with maturity. The wings now begin to be folded more closely to the body. The bird begins to use the legs to raise the body (Plate II., 19.2, 8, 8). With this the wings cease to be used for this purpose in the food reaction. For several days the first joint of the legs, from the foot to the knee, is still used as foot, and the foot alone is not used to stand on as in the adult bird before the nest is left (Plate II., 21.8). By the eighth day the birds use the toes to grasp a stick and will remain perched on one if carefully placed there, although their bodies lie down flat upon it at the same time. By the tenth day they can maintain a standing posture, and will sit somewhat erect when perched on a stick. During this period such activities as scratching the head, and preening the feathers appear. The Grosbeak, Chipping Sparrow and Redwing usually leave the nest between the ninth to twelfth day. The Brown Thrush, Robin and Mourning Dove leave it two to five days later. At this time they can fly from a few feet to a hundred yards, depending on whether they leave the nest a few days early or late. The second and third attempt, if made immediately after the first, is much less successful. A young bird that can fly one to two hundred yards the first time can usually be caught the third to fifth time, if followed up immediately, in all probability simply a matter of fatigue. Their manner of flying at this time is readily recognized as that of a young bird. It is slow, and the body is carried more in a diagonal instead of a horizontal position, as is the case with the adult bird. The stroke of the wings also seems somewhat different, but in what ways has not been determined.

(*d*) *Relation of Growth in Strength and Acquisition of Coördinations Proper.*—In these three stages of acquisition of motor coördinations we must now distinguish more sharply between growth in neuro-muscular strength and acquisition of coördinations as such. The observations on the relation be-

tween these two factors may be expressed briefly in the generalization that *coördination*, the ability to use the right muscles in the right combinations and order, *appears and develops before the neuro-muscular strength necessary to make the movements effectively*. This is seen best in the use of the wings to brace and raise the body in the food reaction, and in the efforts to stand, to raise the body on the feet. The wings are used in this way from the time of hatching till the beginning of the third stage of motor development, when a standing posture begins to appear. The manner of use does not change essentially during this time, but its efficiency due to growth in strength does. This is seen quite well in the illustrations in Plates II. and III. In like manner efforts to raise the body on the feet begin in a coördinated way before there is sufficient energy to do so. From the seventh to ninth day the Redwing was often observed to crawl backwards when placed on a smooth surface. On a closer study of this behavior it was found to be due to this attempt to stand when sufficient strength was still lacking. The body is raised only slightly and the direction of the force from the contracting leg muscles causes the body to fall backwards, leaving the feet in a forward position. Further attempts to stand then pushes the body backwards directly. This position is well illustrated in Plate II., 21.5. A study of Plate II., 21.3, 7, 19.2, 21.5 and 21.8 will show the mechanism of this behavior, and also the development of neuro-muscular strength following that of coördination. It might be added also that the wings are used in a coördinated way for flying before there is strength enough to fly. But here the matter is complicated by the fact that the wing feathers are not full-grown until some time after the coördinations appear. The prominence of fatigue, however, in the first repeated efforts at flight just after the birds leave the nest is again an illustration of this phenomenon.

(*e*) *Relation of Heredity and Exercise*.—The observations on the acquisition of motor coördinations and neuromuscular strength may justify a word in regard to its hereditary character, and the rôle of exercise. They have left the general impression that exercise plays little or no part in this acquisition.

But a proof of any such assumption is at present quite impossible. The impression gains its force from three sources. First, from the fact just considered, namely, that coördinations precede efficient neuro-muscular strength. If exercise were required to establish these coördinations one should expect that on the whole the order would be the reverse. There should be first the required strength to make movements, which with repetition would fall into the right coördinations. Secondly, some of these coördinations are present from the start. The complex coördinations of the muscles of the head, neck and wings in the food reaction at the time of hatching are purely hereditary. Thirdly, the amount of exercise for the different activities observed is in some cases not very great. Trying on the wings for flying does not occur until a few days before the birds actually fly. And during these days it may not occur more than several times, as was found when a nest was kept under constant observation throughout the day. Such activities as scratching the head while standing on one foot, and preening the feathers were, when observed for the first time in a nest, not different in character from what they are later, except in ways that can be best explained on the basis of lack of strength. Yet it is evident that we cannot conclude from present observations that exercise played no part at all in those aspects of the different coördinations that were acquired gradually.

3. Relation of Growth in Weight and Acquisition of Coördinations.—We may now consider briefly the relation these observations show between growth in weight and the acquisition of coördinations, using the latter term now again to include both coördinations proper and neuro-muscular strength. The growth curves showed very distinctly three stages of growth that are all quite definitely limited as regards the ages at which each begins and ends. We have also described three stages in the acquisition of motor coördinations. A comparison of the results in the two cases will show that the stages in the latter are fairly closely correlated with the three stages of growth in weight. The first stage of slow but rapidly increasing rate of growth is correlated with acquisition in motor coördinations. The second stage of maximum but

constant rate of growth is correlated with no noticeable progress in coördinations. The third stage of decreasing rate of growth is correlated again with progress in acquiring coördinations. In more general terms, progress in coördinations is greatest when growth is slowest, and while the rate of growth is at its maximum acquisition of coördinations ceases. I am not prepared at present to discuss very much the significance of this correlation. However, it is not to be inferred at once that there is any necessary connection between the two. An improvement in the processes of digestion and assimilation might be responsible for the initial slow rate of growth, while the final decrease in the rate is undoubtedly due here to the same physiological changes that give rise to the same thing in all animals. On the other hand, the rapid acquisition of a few coördinations during the first few days and the delay for the rest until the last few days spent in the nest may be the result of an hereditary adaptation. The coördinations are acquired as they are needed. And it is just as essential that the latter, the ability to use the legs in standing and walking and the ability to fly, should be delayed as that the other coördinations should be developed early. It is their motor immaturity alone as regards these coördinations that keeps the young in the nest and prevents their destruction. These things suggest the possibility that the correlation in question may be incidental, that the stages in growth and in acquisition of motor coördinations are independent. But we shall return to this later.

D. The Food Reaction.

From the nature of the case, the first food reactions must be purely instinctive, both with reference to the nature of the motor response and the kind of stimuli that arouse it. But in regard to the latter at least there is from the first abundant occasion for associations between different stimuli and food to become established. The young are fed at more or less regular intervals throughout the day, varying from about once every five minutes to once every forty minutes. The parent birds have different calls, some of which they use exclusively for the

purpose of arousing the food reaction, and others for other occasions. As they light on the nest they jar it, varying in degree with the manner of construction and support of the nest. After the young are several days old their eyes open, giving the possibility of associating food with the sight of the parent birds. There is then a variety of stimuli with which the young may come to associate food. For this reason the food reaction gives an excellent opportunity for studying the relation of instinctive and intelligent behavior in its reciprocal development. I shall consider (1) the nature of the motor response in the food reaction, and (2) the stimuli that arouse it. In this the Mourning Dove will not be taken into account, since it feeds its young in a different manner, only a few times a day with large quantities of regurgitated food at a time.

1. Nature of the Motor Response.—The motor response consists at first of raising the head and neck into approximately a vertical position and a very wide gaping of the mouth. With growth in strength and coördinations in general, more of the other muscles come into play. But the essential character of the motor response does not change until several days after the young have left the nest. That is, it is not until this time that the young begin to use their bills in pecking at things and to actively take hold of food that is given them. Throughout the period of growth and later the parent bird puts the food well down the throat of the young, leaving nothing to the latter but the reflex act of swallowing. It is then only in the unessential movements involved in raising the body and in the use of the wings that the total motor response in the food reaction develops during the period of growth (Plate III.).

The food reaction is given repeatedly as long as the stimulus for it remains, and continues for some time after the bird has just been fed. The vigor and promptness with which it is given varies with age. It is at its maximum in this respect during the period of maximum rate of growth. But this is most likely due to the young being hungrier at this time. Since they grow faster, they need more food, but the observations so far do not indicate that they are fed more abundantly during this period. The character of the response in this respect

naturally varies at any age with the degree of hunger, and undoubtedly with other physiological states. At any age it also varies with different stimuli, all of which at the given age still call it forth in some degree. When well fed no stimulus may call forth a very vigorous response, while when specially hungry a stimulus that usually gives no response may arouse a very vigorous reaction. These variations in the nature of the response, and as to whether it will be given at all or not, as dependent on these several conditions, are of the first importance in considering the different stimuli that call forth the food reaction at different ages. It results in an irregular course of development that may show only a general progress in a given direction. On any given day in the particular case the reactions may be what they normally are a day or two earlier or later. We shall see that this is in general the case.

2. STIMULI THAT AROUSE IT.—Two methods were employed to determine what the stimuli were to which the food reactions were given at different ages, for it was found at once that they changed with the age of the young. The first was simply that of general observation, noting as carefully as possible the natural conditions under which the young reacted. The second consisted of testing their food reactions daily with artificial stimuli, some of them being rough imitations of the natural stimuli. The latter was carried out systematically only with the Redwing and Brown Thrush. The artificial stimuli thus employed were as follows: (1) Imitated cluck of the parent bird, (2) a one-note whistle, (3) a clap of the hands, (4) a short hiss, (5) jarring of nest by tapping it with a pencil, (6) a rapid pass with the hand and extended first and second fingers towards the young. Each was repeated once or twice at about one second intervals. An obvious objection to testing the food reaction with these artificial stimuli is that the manner of their production is very crude and poorly standardized. We shall see, however, that in spite of this a number of things have been determined by their use.

(*a*) *The Natural Stimuli.*—The observations on the natural conditions and stimuli that arouse the food reaction will serve to give a general account of the changes that occur

with age. I shall give these first. During the first day or two many of the food reactions are of a spontaneous character. When there are no observable external stimuli of any sort present and all the young are lying perfectly quietly in the nest, one will occasionally give a food reaction, the head dropping down again after two to three seconds. These spontaneous reactions disappear very soon. Usually none occur after the first day. The first external stimuli that arouse the food reactions are the special clucks of the parent birds, used especially for this purpose, and tactual stimuli through jarring of the nest when the parent bird lights on it, or from the wrigglings of the young themselves in the nest. According to the observations, the cluck from the first arouses the reaction a little more readily than do the tactual stimuli. But since the observations usually began when the young were already several hours old, we cannot be certain that the effect of experience was not already present. Experience would effect the establishing of the association between food and the cluck, and between food and the tactual stimuli differently. For the young may move about in the nest more or less constantly, and reactions to this are then not usually followed by food. The same holds true for the jarring of the nest when the nature of its supports allows it to swing and shake in the wind. This might tend at first to eliminate the reaction to tactual stimuli until the particular kind of jarring due to the old bird lighting on the nest is discriminated from the rest. In the reactions to the different artificial stimuli we shall see the evidence for this. Individual birds of the same species vary widely in the amount of use they make of the cluck to arouse the food reaction. But in most cases they have been observed to resort to this when the food reaction was not given immediately on their arrival at the nest. After a few days the predominant mode of reaction is to the jarring of the nest caused by the parent bird lighting on it, and is given promptly to this stimulus. The cluck is eliminated because it is not required, and the young do not react to other calls of the parent nor to the sound of its wings when it flies within a foot of the nest without lighting on it. Individual habits of the parent birds and the structure

of the nest may cause exceptions to this rule. By the second to third day after the eyes of the young open they begin to give the food reaction to the sight of the approaching parent. In the course of another day or two this becomes the predominant mode of reaction.

On the whole, then, we have several definite changes in the stimuli that arouse the food reaction. With any individual nest these changes are often quite abrupt, being made completely in the course of twenty-four hours. These changes seem to be made entirely on the basis of experience. The young simply learn progressively to associate food first with the cluck, then with the jarring of the nest, then with the sight of the approaching parent bird. As fast as this takes place the stimuli that aroused it at first are eliminated as a means of arousing it, first the cluck because it is no longer given when it is no longer needed, then the jarring of the nest because the reaction takes place through sight before the nest is touched. That food should become associated first with the cluck rather than with the jarring of the nest as the parent bird lights on it, is accounted for by the fact already stated; the tactual stimulus from this jarring has to be discriminated from other tactual stimuli, from that of the wrigglings of the other young in the nest, from that of the parent bird brooding them, and from that of the swaying of the nest in the wind. All that is required is that the reaction should at first take place instinctively to any kind of stimulus, no matter what its nature. Experience can then perhaps teach the young to inhibit the response to some stimuli as well as to give it more readily to others. The results obtained with the use of the artificial stimuli with the Redwing and the Brown Thrush will throw more light on how readily these associations are formed, but will also show that the reactions in this case may not be so simply explained.

(*b*) *The Artificial Stimuli.*—In preliminary tests with a large variety of artificial stimuli it was found that just after hatching the young would give the food reaction to practically any kind of auditory or tactual stimulus. But later they ceased to give this reaction to most or all artificial stimuli.

We seemed to have, then, in this food reaction an illustration of a law observed in other aspects of animal behavior, namely, a definite instinctive reaction aroused by no one definite stimulus only, but by a large range of quite different stimuli, which through experience comes later to be aroused by certain stimuli only. To test this idea the artificial stimuli used to study food reactions were so chosen as to approach the character of the natural stimuli in different degrees. The imitated cluck, the whistle, the jarring of the nest all approach the character of the latter in some measure. The clap of the hands and the hiss in no way, excepting duration, resemble anything the young birds experienced in their natural environment. If then experience and association alone produced the progressive changes in the food reaction as regards the stimuli that arouse it, those artificial stimuli that resemble the natural stimuli most should continue longest to do so, while those that resemble the natural stimuli least should soon cease to arouse the reaction. In general, the results show that this is the case. But there are exceptions and certain aspects of the results which strongly indicate that the matter is complicated with other factors. We may turn now to these results.

During the first two days all the stimuli used, excepting of course the visual one, aroused the food reaction about equally readily. By the third to fourth day differences for the different stimuli appeared. Food reactions to the whistle and clap of the hands practically ceased after the fourth day. To the hiss they ceased one to two days earlier. To the imitated cluck and jarring of the nest they ceased only after the seventh day. But while in the case of the former the food reaction was at its maximum during the first two days, for the imitated cluck the reaction was given most readily from the third to the fourth day, and for the jarring of the nest it was most prominent from the third to the sixth day. The food reaction to the approach of the hand and extended first and second fingers occurred for the young of some of the nests only, and could never be aroused in the majority of cases. It occurred from the eighth to the tenth day. Put into brief form and excluding scattering exceptions, we have, for the Redwing

alone, the following periods during which the food reaction was given to these artificial stimuli.

Imitated cluck	first to seventh day.
Jarring of nest	first to seventh day.
Whistle	first to fourth day.
Clap of hands	first to fourth day.
Hiss	first to third day.
Sight of hand	eighth to tenth day.

These figures represent the limits within which the food reaction to each of the stimuli used began and ceased to be given by *any* of the young observed, excepting a few individual instances of reactions that were very clearly quite exceptional. Individual variation, however, and variation with the physiological conditions mentioned were large. It follows, therefore, that for any particular bird, these periods were usually quite different. The changes in the reactions were also often strikingly abrupt. It will be important to keep these facts in mind. A more correct idea of the nature of the changes for any particular bird is to be gained by considering some individual cases. The following is a typical record for the Redwing:

No. 28. Redwing.—Two eggs, first hatching June 22, the second, June 23.

June 23. First and second day. Both give the food reaction to all the stimuli.

June 25. Third and fourth day. Both give the food reaction to the imitated cluck. Both give no reaction to the whistle, clap of the hands, jarring of the nest. Both give slight reaction of fear to the hiss.

June 26. Fourth and fifth day. Both give no reaction to the imitated cluck, whistle, clap of hand, jarring of nest. Both give reaction of fear to hiss.

June 28. Sixth and seventh day. Both give no reaction to whistle, and to clap of hands. Oldest gives slight reaction of fear to imitated cluck, pronounced reaction of fear to hiss. Youngest gives slight reaction of fear to hiss.

June 29. Seventh and eighth day. Both give reaction of fear to all stimuli.

June 30. Eighth and ninth day. Both give slight reaction of fear to imitated cluck, pronounced to hiss; no reaction to other stimuli.

July 1. Ninth and tenth day. Both give reaction of fear to all stimuli.

July 2. Both have left the nest.

The following is a record for the Brown Thrush:

No. 35. Brown Thrush.—Three eggs, first hatching July 22, second and third, July 23.

July 22. First day. Food reaction is given to all stimuli excepting the clap of the hands.

July 23. First and second day. All give food reaction to the whistle and to the imitated cluck. All give no reaction to jarring of the nest, or to the hiss.

July 24. Second and third day. All give no reaction to any of the stimuli.

July 25. Third and fourth day. All give no reaction to any of the stimuli.

July 27. Fifth and sixth day. Reactions same as on July 24 and 25, excepting that the oldest gives reaction of fear to the hiss.

July 28. Sixth and seventh day. All give reaction of fear to the hiss. All give no reaction to all other stimuli.

July 29. Seventh and eighth day. All reactions the same as on July 28.

July 30. Eighth and ninth day. All give food reaction to approaching hand and extended finger. All other reactions same as on July 29.

July 31. Ninth and tenth day. All reactions same as on July 30.

August 2. Twelfth and thirteenth day. All have left nest.

These records may be taken as representing the general result on the degree of regularity of the changes and their abruptness. The latter, however, is seen more strikingly in some of the illustrations of Plate III. In 18.1 we see the two younger ones, first day, giving the food reaction to the whistle, and the two older ones, second day, failing to respond. In 21.4, two, sixth and seventh day, are giving the food reaction to the imitated cluck, and the largest one, seventh day, failing to respond. In 32.1 all are giving a very vigorous food reaction to the imitated cluck. In 32.3, a day later, the two older ones, fifth day, have ceased to react to this stimulus.

In these observations with the artificial stimuli we may now call attention to several things which make the interpretation of the changes in the food reaction to this class of stimuli on the basis of experience and the formation of associations alone difficult. The first is the fact that the food reaction ceases for the hiss before it does for the clap of the hands. Both of these would seem to be about equally unlike any of the natural stimuli, and if this is correct the reaction to them should be equally affected by experience. Secondly, we see that stimuli that at first arouse the food reaction later give a reaction of fear. Thirdly, the change in the reaction to the different stimuli, from food reaction to no reaction, and from no reaction to the reaction of fear, is often quite abrupt. In this connection we may add at present that the process of forming an association is a gradual one. In the present case it is not completely formed between food and the cluck until the third to fourth day, and for the jarring of the nest it appears at its strongest slightly later still. On the other hand, we shall

see later that changes in the reaction to fear are purely instinctive and occur abruptly. From these facts it becomes obvious that the changes in the food reaction as due to the formation of associations may be complicated with a developing instinctive fear. I shall postpone the full interpretation of these observations until after we have considered the development of fear.

E. The Development of Fear.

The present-day view of fear in birds, as in other animals, which is most widely accepted is that it begins in the form of a generalized instinct. Birds first fear the unusual and the strange in general, and later come to fear particular things as a result of unpleasant experience having become associated with them. Different species show fear in various degrees, and the age at which it appears also varies with the species. For the class of birds that we have observed Herrick states that fear is usually shown about the time the wing feathers develop, that is, in general, a few days before they leave the nest, and that it appears quite abruptly. At this age young birds are apt to leave the nest through fear when approached too closely. To Herrick's observations we shall be able to add that fear in other forms is shown at a much earlier date, and that in some birds its form of manifestation changes several times from its first appearance until maturity is reached. On the basis of our observations on the food reaction and the development of fear together, I shall also attempt to justify some modification of the general view of the relation between instinct and association in the fear of the adult animal.

The method of studying the development of fear in these birds was limited to the use of the artificial stimuli. In their natural environment few things occur that occasion the arousal of fear. General observation without the introduction of other than the natural stimuli can therefore yield but few results on the nature of its latent development. The artificial stimuli employed in a systematic way for this purpose were those used at the same time for the study of the development of the food reaction. In a less systematic way some of these and others

were used in observations on the Chipping Sparrows, Robin and Grosbeak. We shall consider (1) the different manifestations of fear and order of development, and (2) the nature of its development and relation to the nature of the stimulus.

1. *The Different Manifestations of Fear and Order of Development.*—With individual exceptions, fear appeared in five different forms from the time of hatching until the young left the nest. These may be stated briefly as follows: (*a*) I shall regard the cessation of giving the food reaction to stimuli that at first aroused it as due in part to a developing latent fear. The justification for this will appear later. (*b*) The first external and visible reaction of fear consists of a sudden shrinking or shiver to a stimulus. This lasts only a second, and does not involve a special use of the limbs or change in position. (*c*) Following this is a period during which the bird crouches to a stimulus. In this the limbs and head are drawn in, and the birds hug closely the bottom of the nest, usually closing the eyes if they are already open, and lying perfectly quietly for some time after the stimulus (Plate IV.). (*d*) Next is a briefer period during which the birds may not crouch, but remain on the alert and with wide-open eyes follow moving objects in an attitude which may be interpreted as that of alarm (Plate IV.). (*e*) Soon after this the birds will attempt flight and escape when approached. After dropping to the ground from inability to fly or from fatigue they will run to cover, hide and crouch close to the ground. Of these different manifestations of fear the first three were not observed in the Mourning Dove, the first necessarily not, because it gives no food reaction to any of these stimuli. The second was not noted in the Chipping Sparrow, Robin and Grosbeak, but is probably present in these also, simply having escaped observation because it was not systematic enough on this particular point. For the Robin a sixth is to be added, which we may call fighting fear. The first evidence of this appears in connection with the last part of the third stage of development, the crouching in the nest. In this crouch the robin will sometimes simultaneously open its bill in an attitude of fight (Plate IV., 7.11). Later, it will defend itself in this way when caught (Plate IV., 7.13). With

these exceptions, all the birds observed showed a progressive development of fear through the five stages or periods given. Fear in these birds is, therefore, not long delayed, and its development is in one sense quite gradual rather than abrupt. It passes through several forms of manifestations which on the whole are increasingly expressive of fear. The change from one form of manifestation to another, however, is a different matter. We may consider now the nature of these changes and their relation to the nature of the stimulus.

2. *Nature of Its Development and Relation to the Nature of the Stimulus.*—I shall consider each of these several manifestations of fear separately, and in the order given. (*a*) A period of no visible external reaction to all stimuli, excepting the hiss, that at first aroused the food reaction preceded in all cases observed the first visible manifestations of fear. This cessation of the food reaction is with the individual bird usually quite abrupt. It may react quite readily to all these stimuli on a given day and fail entirely to respond to any of them twenty-four hours later and after that (See Plate III. again). But variations in hunger and probably other physiological conditions often make this first change irregular, so that for a while on different hours or days it may alternately give the food reaction or make no response. For a group of birds considered together the 'no reaction' will occur from the first to the second or third day of the third stage of development of fear, the crouch in the nest. For such a group the no-reaction will then be quite infrequent for all stimuli during the first few days, will increase in frequency at different rates for different stimuli, and cease abruptly for all stimuli by about the eighth day. For the Brown Thrush it appeared distinctly earlier than for the Redwing. This general description holds true entirely only for the behavior to the whistle and the clap of the hands. For the Redwing no intermediate period of no reaction was observed for the hiss. It practically ceased giving the food reaction to this stimulus by the third day, and gave the reaction of fear, shrinking, to it as early as the second day. Minor differences as dependent on the nature of the stimulus were observed for the imitated cluck and for the jarring of the nest.

For the latter the no-reaction was more frequent during the first three days than it was for the other stimuli, and decreased in frequency from the third to sixth day. For the imitated cluck it was less frequent than for other stimuli until about the seventh day. These differences in the reactions for the different stimuli, for this and other stages in the development of fear, are important for the general interpretation of the results.

(*b*) The shrinking from a stimulus, consisting of a sudden contraction of all the muscles and immediate relaxation, was never aroused by any of the stimuli except the hiss. It belongs to a period extending from the second to fifth day, inclusive, during which period the other stimuli aroused either the food reaction or no reaction at all. The low degree of motor development at this time makes the crouch for the most part impossible. But since the reaction is so distinctly different in character from the crouch in other ways than would be determined by this motor immaturity, it is not to be regarded as the same reaction. The crouching in a measure hides the young in the nest, and is probably adaptative. We can see no such purpose or adaptative value for the shrinking.

(*c*) The hiss aroused the first definite crouching in the nest (Plate IV., 32.2). For all the other stimuli the crouch was observed for the first time on the sixth day, and by the seventh it was already pronounced.[3] The transition to this manifestation of fear was, therefore, very abrupt. As already noted, food reactions to all stimuli, excepting occasionally the visual one of the approaching hand, ceased the seventh day. From the seventh to the ninth day then the behavior to all stimuli was either no reaction or a crouch, the latter increasing rapidly in prominence and frequency. By the ninth day all stimuli always aroused a crouch in the case of the Redwing, the Robin and the Brown Thrush (Plate IV., 21.7, 7.11, 32.2).

(*d*) During the latter part of the period in which the birds crouch in the nest to different stimuli they show alarm to moving objects, when they are placed outside the nest. Occasionally

[3] A buzzing sound made with vibrating lips or tongue was for the Robins found to be equally effective with the hiss in arousing the crouch before other stimuli did. This sound was not used for the other species.

at this time they show this alarm while in the nest instead of crouching. This is true of all when just on the verge of the next stage of development, and is the rule for the Grosbeak several days earlier. For the Redwing it appears about the tenth day, for the Brown Thrush, Mourning Dove and Robin from one to five days later. This is a short period. A day or two later this suspicious glance on being approached is followed suddenly by a wild scramble out of the nest or by flight, according to the degree of motor maturity (Plate IV., 4.2, 21.9, 38.4). This last stage or form of manifestation of fear (*e*) may then be regarded simply as a further development of the process in the preceding stage. The look of alarm is anticipatory to the attempt to escape.

3. *Its Instinctive Character.*—After this description of the development of fear it should be unnecessary to discuss the question as to whether these different manifestations of fear are purely hereditary or are due in part to experience. I shall regard the observations as conclusive on this point. These reactions are purely instinctive in their origin, affected by experience only on the side of inhibition. Experience with a given stimulus may inhibit the reaction of fear, but there has been nothing in the experience of these birds which would cause them to fear these stimuli in the first place; there could have been no unpleasant association connected with them. Further, experience could not have taught them to express their fear in these several different ways, and to make the changes at just the periods as observed. Thirdly, some of the changes occurred very abruptly, while the formation of associations in other spheres is seen to be more gradual.

F. The Relation of Instinct and Association in the Development of their Behavior.

We are now in position to attempt an interpretation of the exact relation of the factors in the changing behavior to the different stimuli that first all arouse the food reaction and later all arouse a reaction of fear. Without reviewing the observations for this purpose, let me state my interpretation now in brief terms. The food reactions to all stimuli alike at first

are purely instinctive. With the frequent repetition of some of them and feeding following immediately, the association between these and food becomes established more or less gradually. This involves at the same time a growing discrimination between different stimuli, which immediately after hatching is probably almost entirely absent, and which remains very crude through the whole period of growth. This growing power of discrimination is seen in the difference in the nature of the changes in the reaction for the different artificial stimuli, which resemble the natural ones in different degrees. That it is very crude during the larger part of the period of growth is seen in the fact that the discrimination between the artificial and the natural stimuli is absent so long where they resemble each other so little. The strongest evidence for this is in their inability to distinguish an approaching hand from the parent bird when they are already eight to ten days old. This discrimination between stimuli that mean food and stimuli that do not, between the imitated cluck and the hiss, for example, might perhaps alone account for the food reaction coming to be given more readily for the one class and to be inhibited for the other. But if the observations on fear are also taken into account in this connection there is some indication that this instinctive fear is a factor in the inhibition of the food reaction to certain stimuli that at first aroused it. In other words, some degree of association of food with certain stimuli follows at once the ability to discriminate the stimuli, and with this discrimination and association goes simultaneously an instinctive fear of all stimuli with which food is not associated. From this point on, ability to make discriminations, formation and strengthening of associations, and intensity of instinctive fear develop together, probably through reciprocal influences, with only a certain degree of independent development. Special evidence for the instinctive character of the inhibition of the food reaction is given in the abruptness of its appearance in individual cases, and in the abruptness of the changes from one manifestation of fear to the next form.

In connection with this interpretation, and the general characteristics of fear as observed, we may suggest some modifica-

tion of the general view of the relation between association and instinct in fear in animals that is at present most widely accepted. This general view, as stated above, is that fear begins in a generalized instinct causing animals at first to fear everything that is unusual or strange. Later they fear particular things only, and because unpleasant experiences have become associated with them. Our observations verify the first part of this view. But the early appearance of fear, and its intensity purely as an instinct do not suggest that conditions will arise very readily under which the animal can learn through experience whether certain things are to be feared or not. An animal will fear and continue to fear instinctively everything for which it has no great use, or for which there are no special causes for not avoiding it. The particular things feared later, then, are those that have not yet been eliminated through the taming process through special conditions arising that have overcome the original general instinctive fear and thus made experience with these things possible. This makes it more likely that the fear for particular things only is still instinctive than that it is acquired through experience. Indeed, the process suggested here would seem to have the greater biological value. If the original instinctive fear were overcome excepting under conditions that put a premium on boldness many animals would be destroyed before learning much through experience.

G. The Relation of Growth to the Development of Associations and Fear.

We have seen above that there were three periods of growth; a period of slow but rapidly increasing rate of growth from the first to the fourth day, a period of maximum and constant rate of growth from the fourth to the seventh, and a period of decreasing rate after the seventh day. I have also described three periods in the acquisition of motor coördinations and pointed out that these were fairly closely correlated with the three periods of growth. A few coördinations are acquired during the first period of growth, with practically no progress in coördinations during the second period, and a rapid progress with the beginning of the third period of growth. We now

see that the first period of growth is also the time during which the first crude discriminations and associations are established. After the fourth day the food reaction ceases rather abruptly for the whistle, the clap of the hands, and has already ceased a day or two earlier for the hiss. These are the artificial stimuli that are most unlike the natural stimuli. During the next period of growth from the fourth to the seventh day the readiness and frequency with which the food reactions are given to the imitated cluck and to the jarring of the nest increases some. This is the effect of a growing association between food and the natural stimuli, which these artificial stimuli resemble most, combined probably also with slow progress in the ability to make the finer discriminations between these imitations and the natural stimuli. With the beginning of the last period of growth comes an abrupt change in nearly all the reactions. The food reaction is no longer given to any of the stimuli, excepting occasionally the visual one, and manifestations of fear appear definitely and quite abruptly in the form of crouching in the nest, which now very rapidly becomes the predominant reaction to all artificial stimuli, followed in rapid succession by other forms of manifestation of fear for these stimuli. This correlation between growth and progress in the development of associations and of instinctive fear for these stimuli strengthens the probability that the correlation between growth and acquisition of motor coördinations is due to some inherent connection and not incidental, as was suggested before. These correlations as shown by these preliminary observations raise a host of highly important questions on which the present results need further investigation before a definite decision can be offered.

H. Summary.

The relation of instinct and intelligent behavior in the different natural activities of adult animals is a fundamental problem. Its solution demands the study of animal infancy, during which period many of these activities are acquired. There is great need of more efficient methods of getting systematic observations on these natural activities.

For the species observed, there are three distinct periods of growth in weight. First, a period of slow and increasing rate of growth, from the first to about the fourth day, inclusive. Second, a maximum and constant rate, from about the fourth to the seventh day. Third, a decreasing rate of growth, beginning about the seventh day.

There are three stages in the acquisition of motor coördinations, fairly closely correlated with the three periods of growth. During the first a few coördinations are acquired. The second stage, from about the fifth to the seventh day, is characterized by a lack of progress in acquiring coördinations. The third, beginning about the seventh day, is characterized by a rapid development of coördinations.

Coördinations proper, the ability to use the right muscles in the right order, precedes the neuro-muscular strength necessary to make the movements effectively.

Exercise probably plays little or no part in the acquisition of motor coördinations.

Just after hatching, the food reaction is a purely instinctive response. For the first day or two it is often given in the absence of any observable external stimulus. For the first several days it is also given instinctively to practically every kind of tactual or auditory stimulus. A definite association is formed first between the special cluck of the parent bird and food. Next this association is formed with the tactual stimulus from the jarring of the nest as the parent bird lights on it. The reason for this order is probably to be found in the fact that the young have to learn first to discriminate between this particular tactual stimulus and several others resulting from movements of the other young in the nest, from shaking of the nest in the wind, and from the parent bird brooding them. By the second or third day after their eyes open the association is formed between food and the sight of the approaching parent bird. These changes in the food reaction from its initial instinctive form are probably all to be explained on the basis of experience and association. But changes with age in the reactions to certain artificial stimuli (imitated cluck, a one-note whistle, a clap of the hands, a jarring of the nest by tap-

ping it with a pencil, a short hiss, and rapid approach of the hand and extended first and second fingers) cannot be entirely explained in this way. Just after hatching the food reaction was given to all artificial stimuli about equally readily. It ceased to be given to the imitated cluck, and to the jarring of the nest by the seventh day, to the whistle, and to the clap of the hands by the fourth, to the hiss by the third, and to the sight of the approaching hand it was occasionally given from the eighth to the tenth day. For individual birds these periods were usually quite different, and the changes were often very abrupt. The interpretation of the changes in the food reaction to these artificial stimuli must take into account the simultaneous changes in the developing reactions of fear, given to these same stimuli.

Fear developed gradually and appeared in five different manifestations, in the following order: (1) Cessation of the food reaction to stimuli that at first aroused it. (2) A momentary shrinking to the stimulus. (3) Crouching in the nest, consisting of drawing in the limbs and head and hugging closely the bottom of the nest. (4) An attitude of alertness and attentive watching of moving objects. (5) Escape from the nest when approached. These different reactions of fear lasted for unequal periods of time. They also appeared at different ages for the different artificial stimuli used. With the individual bird the transition from one form to the next was very often completely established in twenty-four hours. In general, those artificial stimuli that resembled the natural stimuli most aroused the food reaction longest, but by the seventh day all, excepting occasionally the visual stimulus, ceased to arouse it, and give instead the reaction of fear. The hiss aroused the reaction of fear earlier than any of the other stimuli.

The development of these different manifestations of fear is undoubtedly purely instinctive, affected by association only on the side of inhibition, and in so far as the power of discrimination and associations develop reciprocally.

For the development of behavior as regards the food reaction to the artificial stimuli and the different manifestations

of fear, I offer the following interpretation. The first food reactions are purely instinctive, accompanied by little or no power of discrimination, which discrimination remains very crude throughout the period of growth. Discrimination and formation of associations between food and certain stimuli probably develop simultaneously. All stimuli with which no pleasant associations are already formed are then at the same time instinctively feared. Developing fear, therefore, plays a part as well as the formation of associations in the changes in the food reaction to the different artificial stimuli, which is seen especially in the fact that the formation of associations is a gradual process, while the change from one manifestation of fear to the next form is frequently very abrupt. These observations suggest a modification of a part of the present-day theory on the relation of instinct and association in the fear of adult animals, namely, that they come to fear particular things not so much because of unpleasant associations that are connected with them, as because the taming process has not been completed. Their fear for particular things remains in the main instinctive.

The correlation between the three periods in the growth in weight and the periods in the acquisition of motor coördinations holds also for the former and stages in the development of associations and the manifestations of fear. The first crude discriminations and associations are made from the first to the fourth day, and this period marks also the beginnings of instinctive fear. From the fourth to the seventh day there is some improvement in discrimination, and a perfection of associations between food and certain stimuli. With the beginning of the last period of growth there is an abrupt change in all the reactions, the food reaction ceasing for all the artificial stimuli, excepting occasionally for the visual, and fear begins to develop rapidly through several forms of manifestations.

PLATE II.

27.1. Redwing. First stage of motor coördinations.

24.4. Redwing. First stage of motor coördinations.

21.3. Redwing. Second stage of motor coördinations.

19.2. Redwing. 6 and 7 showing second stage of motor coördinations; 8 and 9 showing the beginning of the third stage.

21.5. Redwing. End of second stage of motor coördinations, showing insufficient neuro-muscular strength for making the acquired coördinated movements effectively.

21.8. Redwing. Third stage of motor coördinations.

17.1. Redwing. Third stage; coördinations at time of leaving the nest.

PLATE II.

2 2

27.1

3 4 4 3

24.4

6 7 7

21.3

7 8 6 8

19.2

8 8

21.5

10 10

21.8

13

17.1

PLATE III.

35.1. Brown Thrush. Food reaction to hiss.

18.1. Redwing. Food reaction to whistle by 1 and 1; inhibition of reaction by 2 and 2.

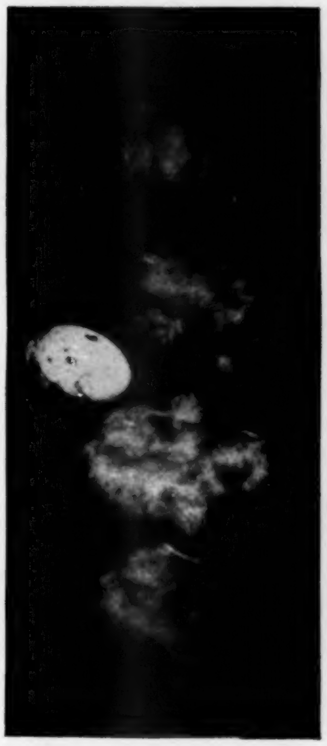
32.1. Brown Thrush. Food reaction by all to imitated cluck.

32.3. Brown Thrush. Food reaction to imitated cluck by 4 and 4; inhibition of reaction by 5 and 5.

21.4. Redwing. Food reaction to imitated cluck by 6 and smaller of 7; inhibition of reaction by larger of 7.

22.4. Redwing. Food reaction to approaching hand with extended index and second finger.

PLATE III.



18.1

21.4

22.4

35.1

32.1

32.3

PLATE IV.

32.2. Brown Thrush. Second stage in development of fear. Crouch in nest to hiss.

21.7. Redwing. Second stage. Crouch in nest on being approached.

7.11. Robin. Reaction of crouch in nest combined with reaction of defense (fighting fear) to approach of hand.

7.13. Robin. Reaction of defense to approach of hand.

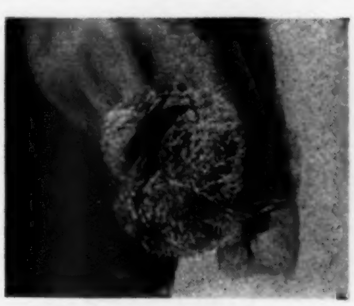
4.2. Rose-breasted Grosbeak. Third stage of fear. Attitude of alarm in reaction to presence of person and camera.

21.9. Redwing. Third stage of fear. Attitude of alarm to moving hand at camera.

40.5. Mourning Dove. Absence of external manifestation of fear to handling.

38.4. Mourning Dove. Attitude of alarm to presence of person and camera.

PLATE IV.



40.5 9

4.2 9

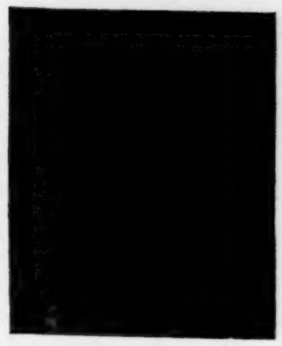
21.9 10

38.4 12

21.7 10 10

7.11 12 13

7.13 15



32.2 4 5

THE DEVELOPMENT OF IMAGINATION IN SCHOOL CHILDREN AND THE RELATION BETWEEN IDEATIONAL TYPES AND THE RETENTIVITY OF MATERIAL APPEALING TO VARIOUS SENSE DEPARTMENTS.

BY STEPHEN S. COLVIN AND E. J. MYERS.

CONTENTS.

Introductory Statement.

During the winter and spring of 1907 an experiment to determine the ideational type of school children and the development of these types during the school years was performed on five hundred and twenty children in the public schools of Champaign, Ill. The ages ranged from eight to twenty. Later the experiment was supplemented by conducting a similar investigation with about seventy-five students, members of the elementary classes in psychology, in the University of Illinois, and still later with about two hundred such students. These tests were directed towards discovering whether the subjects were predominatingly of a visual, motor, auditory or of a mixed type. The subjects were presented both visually and orally with cards containing angles and nonsense characters, and with nonsense syllables. During some of the tests the motor memory was aided by supplementing the ordinary method of learning by tracing the visually or orally presented words with the blunt end of a pencil on the desk; during others the learning was impeded by the subject holding his tongue between his

teeth while studying the words. The memory was then tested for immediate recall and in some instances for recall twenty-four hours later.

A second part of this experiment aimed to discover the relation existing between the various types of imagination and the learning of material appealing to the three chief sense departments (visual, motor, auditory). More especially, the question was asked, "Does the visually minded subject learn more readily material with a visual content, the motor minded material with a motor content, the auditory minded material with an auditory content, or can the visually minded learn as well material with a motor content, etc.?" To test this a simple story, interesting to all grades, was composed which had in it an equal number of words and phrases suggesting the three different types of ideation. The test was here made for both immediate and for delayed recall. A detailed statement of the method and results of these experiments follows.

The tests were all given in the same period of the day, from 9:00 A.M. to 11:30 A.M., and under similar conditions. This period was selected because it was considered to be the time when the children are least fatigued and most liable to put forth their best efforts. The tests were given to the pupils in their own rooms in the school building. The conditions of the rooms were much the same. All were neat, well lighted and ventilated, well governed and had from thirty to forty pupils in a room.

In making the investigation, two things were guarded against. First, care was taken that no suggestions or helps should be given unintentionally by the person making the test; and second, that the pupils should not be fatigued. To avoid errors that might arise from these two sources the writer (M) gave the tests without assistance from the teachers. To overcome the danger of timidity on the part of the pupils, a few moments were taken in which the experimenter sought to gain their confidence.

The condition sought was such as would insure the maximum effort from all. The room was closely watched and in case a pupil did not try, or received help, which was rare, his

paper was quietly discarded. The tests were alternated, in such a manner that they would not become tiresome.

I. Résumé of Previous Experiments in this Field.

The determination of the particular ideational type of children has already been made, directly and indirectly, the subject of several investigations in the psychology and pedagogy of the learning process. Among the most extensive studies is that of Netschajeff who tested the development of memory in 687 children in the schools of St. Petersburg. He presented to them various visual objects, tones and noises, numbers, words appealing particularly to the visual imagination (such as pencil, bottle), likewise words with an auditory content (such as noise, song); he further presented words signifying emotions (such as joy, hope, sorrow) and finally words standing for abstract ideas (such as cause and effect). Lobsien repeated these experiments with a modified and slightly improved method, using as subjects 461 children in the schools of Kiel. Netschajeff's subjects ranged in age from nine to eighteen years; Lobsien's from eight to fourteen.

The results of these two experiments agree in general and indicate that the various kinds of memory in their development show periods of fluctuation, the most marked being at the onset of puberty. Lobsien found the greatest relative increase between the ages of ten and twelve. Memory for emotional states remains undeveloped until puberty, then it sets in and grows rapidly, but more rapidly with the girls than with the boys. About the same time begins a rapid development of memory for touch and movement and also the memory for numbers.

Boys in the lower grades have the best memory for concrete objects, for words with a visual content and then for sound, touch and movement. Later come memories for numbers, abstract concepts and emotional states. Girls differ slightly, visual words coming first, then concrete objects, sound, numbers, concepts and acoustic words; later still, touch and movement.

Meumann, commenting on these results and on others ob-

tained by himself and his students, concludes that young children are realists, particularly visualists. The mental processes of the adults are more in terms of the general idea.

S. S. Colvin and I. F. Meyer during the year 1904–05 performed on three thousand school children in the State of Illinois an experiment specifically intended to test the development of imagination. The method employed was quite different from that used by the two previous investigators but the results in many instances agree with the foregoing.

The data for this investigation consisted of compositions written on certain selected subjects, and done as a part of the regular school work. A record was made of words and phrases in these compositions indicating visual, auditory, motor, tactile, pain, olfactory, gustatory and organic images. In the same way the compositions were studied to discover evidence of some of the more complex forms of imagination under the head of scientific imagination, the fairy story, the nature myth, the heroic, the dramatic, the religious and melancholic forms of imagination.

It was found that the four highest forms of mental imagery (for both sexes) stood in the following order: (1) Visual, (2) auditory, (3) motor, (4) tactile. Much lower than these and in the order named came pain images, gustatory, organic and olfactory. The most striking feature of the curves representing the development of imagination is the sudden decline at about the age of puberty of most of the types. This is not true of the visual imagination, however, which has its most rapid rise for both sexes at about the fourteenth year. This growth does not, however, mean that there is a constant increase in concrete visual imagery; it rather indicates that the young person uses words more and more in an abstract and symbolic way.

Pfeiffer investigated carefully for three successive years the ideational types of fifteen girls and found that 44.6 per cent. were visual, 25.3 per cent. were acoustic and 30.1 per cent. motor. Pentschew from his investigations concluded, on the other hand, that for children the motor element forms the basis of memory, while the visual is a secondary factor. Pohl-

mann thinks that auditory imagery predominates in the mind of the child.

Lay, who conducted extensive experiments to determine the correct method of teaching spelling, concludes that children are especially motor in their tendency and that vocalization is especially prominent in their thinking.

The chief criticism to a large number of these experiments seems to lie in the fact that no thoroughly adequate method has been employed in determining the various memory types for large groups of children. The following experiment has attempted to obviate this difficulty as far as the visual and the acoustic-motor types are concerned.

The second problem on which the present investigation attempts to throw some light, namely, the relation between memory types and the reproduction of material appealing to these various types, has received up to the present time even less consideration by investigators than has the first. An investigation by Segal bears indirectly upon the question. His particular problem was to test memory types in relation to the learning and the immediate reproduction of material. Among other things he concludes that when presentation and learning are in accord with the memory type, the condition for accurate reproduction is most favorable. For example, visual presentation is most favorable to the visual type and acoustic material to the acoustic type.

II. Methods of Determining Ideational Types.

As has already been said one of the great difficulties in the study of ideational types has been the unsatisfactory methods for determining these types. The method to be adequate for determining the memory type of children must be simple and yet accurate. It must be simple and easily comprehended, because the experiment is to be made with inexperienced observers taken in groups, not with persons accustomed to the laboratory and familiar with the use of psychological terms. The importance of this requisite should not be overlooked as many methods produce excellent results when used with trained observers, but are valueless when used with children. The

test must also be accurate, that is, it must be such as will indicate at once the actual mental processes of the subject. This is especially necessary in an experiment dealing with children in groups. An adult who has been trained in analyzing his own experience, may be relied upon for his introspections, but the same is not true with children who have had no training. This inability of children to report accurately concerning their mental processes was clearly shown in a series of tests made at the beginning of the present study. A test that involved certain distractions was given to a hundred school children in the fourth and fifth grades. Together with the tests was given a list of questions inquiring concerning the effect of the distractions upon their power to memorize. Of the answers given only a little over fifty per cent. agreed with the actual results received from the tests. The children were not accustomed to analyzing their states of consciousness, neither did they clearly comprehend when asked concerning their experiences. Their answers were merely their idea of what they thought was wanted; not an account of their experiences.

Among the best known methods for determining memory types are the 'questionnaire method' first used by Galton; the 'word method' used by Kraepelin; a modification of the 'word method' used by Secor; Binet's method with the letter squares; and various forms of the 'distraction method' used by Meumann and others. These are methods devised in most part for the skilled observer and not for children.

The 'questionnaire method' places much stress on introspection. Two objections to using this method in the present experiment suggested themselves. First, as was said before, children are not capable of accurate introspection.[1] The second objection to the 'questionnaire method' applies to the device as a method both for the experienced and the inexperienced observer. The presence of imagery depends on different factors, such as vividness of stimulus, recency of the experience, repetition of the observation, etc. In the laboratory these factors are carefully noted in the conditions for experimenta-

[1] Compare in this connection Titchener's criticism of the method in his *Experimental Psychology*, Vol. I., Instructor's Manual, p. 389.

tion. They are nearly as important as the reports of the observer. In the 'questionnaire method,' these factors are ignored. A set of questions is asked an observer concerning certain experiences, and the one who asks them may know nothing about the time, place or conditions under which the observer came into possession of those experiences. Suppose a list of questions were given a child in the winter time concerning a garden of roses. He has not been in such a garden for nearly a year where he could smell the odor of the flowers, feel their petals and hear the hum of the bees. He has, however, seen such a garden every day as he passed the greenhouse on his way to school. Under these conditions, other things being equal, the observer's report will be more favorable to the visual than to the auditory or olfactory types. The method may or may not be a fair test for memory type. Much depends on the immediate environment.

The 'word method' used by Kraepelin is no less difficult from the standpoint of the present experiment than the questionnaire method, nor it is less free from criticism. According to this method the observer is required to write down a list of objects characterized by their color; again a list characterized by their sound, etc., it being assumed that the visually minded person will succeed better with the first test, the auditory minded with the second and so on. It would be nearly impossible to use this method with children in a place where color is everywhere to be seen. However, where conditions are such that the observer would be placed where objects of color could not be seen, the method would still be open to the same criticism as the questionnaire method, namely, the past experiences upon which the observer must draw for his material in the experiment would not be taken into account. For instance, had the observer just visited a park or a picture gallery, he could readily name objects of color. The error is that the method assumes a normal environment where color, sound and motion have an equal part in one's experience, which may or may not be true.

A modification of this method was employed by Secor who presented a list of printed words to the observer, who was to

note the imagery that developed in his mind as he glanced at each of the words. This is clearly a method for trained observers and not for school children.

Binet used the letter squares in which, for example, twelve letters of the alphabet were arranged as follows:

P	X	K	B
Y	Q	H	A
F	T	C	V

The observer, after looking at the card with the letter squares for ten seconds, laid it down and attempted to reproduce it from memory, his type of imagery being determined by his introspection. The first part of the method, the reproduction of the letter square, suggests a valuable test for visual memory. Especially is this true in testing the observer's sense of position for the various letters. A modification of this method was used as a test for visual memory in the series finally adopted for this experiment.[2] (See tests Nos. 2 and 3, pages 96 and 97.)

Binet had the observer hold the tongue between the teeth while memorizing syllables in order to impede the kinæsthetic sensations of the speech organs. This was not intended to eliminate motor impressions entirely, but to so weaken them that the loss would be quite noticeable if the observer were strongly of the motor type, the loss being determined by comparing the results of this test with a previous one in which the tongue was free. The method has many advantages over other methods in determining motor memory especially with children. Other forms of the distraction method in which, for example, memory is impeded by having the observer sing or repeat the letters of the alphabet while memorizing the syllables, are too difficult for the average child. Few persons can divide their attention so as to repeat the letters of the alphabet and memorize syllables at the same time. The advocates of this method contend that by constant practice this difficulty may be obviated, the repetition of the syllables

[2] The above described tests together with several others are presented and discussed by Titchener in his *Experimental Psychology*, Vol. I., Instructor's Manual, Chapter XII.

becoming almost automatic, thus eliminating much of the distraction. This may be true with the trained observer, but it is too much to be expected from a group of children. This test was attempted with a class of fifty, who sang the syllable *la,* while memorizing ten syllables. This distraction caused by the noise and the division of attention, was so great that the results could not be relied upon. Binet's method has the advantage in that there is no noise and there is but one thing to attend to.

Meumann advocates the method of distractions (*Methode der Störungen*), on the assumption that the acoustic type is more easily disturbed by auditory stimuli, the visual by visual stimuli, and the motor when the "inner-speech" is hindered.

In connection with this last-named method may also be mentioned the method of aids (*Methode der Hilfen*). Here aids to the various types are used and the type determined by the effectiveness of the aids. This method was used in connection with the method of distraction in determining the motor type in the present investigation.

It has further been noted that the visual type confuses like appearing, but different sounding letters, while the auditory type confuses like sounding but different appearing letters. An attempt was made in the present investigation to apply this as a method of distinguishing between the visual and the auditory types, but the success obtained was so slight and the results so equivocal that it was soon abandoned as impractical.

It has been suggested by several writers that the visually minded person is aided greatly by localization and hence visual memory shows its superiority over the auditory or motor types when such a localization is involved. This principle was made use of in several of the tests made in the present investigation. (See Figs. 1, 2 and 3.)

This principle of localization appears in the recognition of variously placed angles as a test of visual memory. According to this test a series of angles is exposed for the observer to fix in mind. Afterwards, in a promiscuous set of angles, he is expected to recognize the angles previously seen and indicate them by number. The plan assumed that the person having

the most distinct image would most readily recognize the angles on the card. A similar plan is to have a series of letter placed at special angles and then exposed to the observer. After exposing the screen ten seconds the observer is to put the proper letters in angles, which are arranged on a card before him. From those two suggestion came test No. 1 in the present series of tests for visual imagery.

Another test suggested for visual memory was to expose nonsense characters or unfamiliar symbols, such as Hebrew letters, the observer later reproducing the same from memory. The objection to this plan is that the characters, since they are exposed for some time, will probably suggest names, and thus the results will be those of auditory and verbal memory as well as visual. This test, however, suggested the nonsense characters, which combined with the idea of spatial relations formed another test of the series for visual memory.

Various other methods for detecting different types of memory were devised, discussed and modified, which together with these already described, resulted in the series of seven tests for ideational types that were used in this study.

III. The Test with Nonsense Material.

For convenience, the series of tests were divided into two groups. The first group was composed of three tests, each of which was intended to appeal to visual memory. They were composed of characters and spatial relations which eliminated as far as possible any auditory or motor aids. The second group contained five tests in which nonsense syllables were used. These syllables were memorized by visual, auditory and motor methods. The tests with their description follow:

Test No. 1.—The children were seated at their desks in an easy position with pencil and paper. On the paper was a series of four letters duplicated five times. They were arranged in promiscuous order in four lines of five letters in a line. (See Fig. 1, *a.*) On a screen, 22 x 28 inches, there were two lines intersecting at right angles, forming four angles. (See Fig. 1, *b.*) In these angles were placed the four letters found duplicated on the papers that were in

the hands of the children. The object of this test was to determine who could put the proper angles around the largest number of letters taken in order as they appeared on the paper, in a given period of time. The proper angle was the angle in which the letter was found on the screen. After careful instruction, the screen was exposed to view twenty seconds. As soon as the screen was removed, thirty seconds were given for placing the angles around the letters.

The assumption in using this test was that the strongly visually minded person would carry the image of the relationship between letter and angle with him and that consequently as soon as he saw a letter he would also see the angle it was

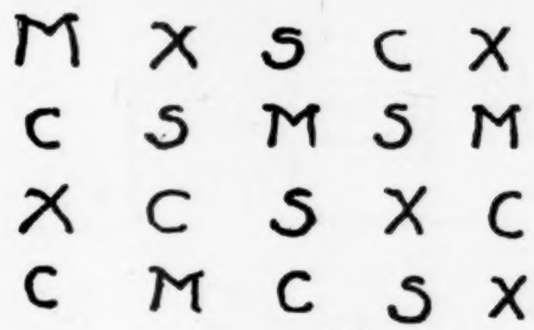


FIG. 1*a*.

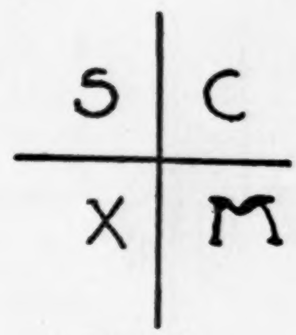


FIG. 1*b*.

in from the mental picture. This would give him a decided advantage, and, other things being equal, his power of visualizing could be estimated from his speed and accuracy in placing the angles. This test worked fairly well in the more advanced grades, but was in general too difficult for younger pupils. There was a decided advantage in favor of the rapid working pupil, since speed was largely the standard of judgment, so that often a person might be classed as visual from the results when his success was due to a larger extent to his rapidity of movement and not to the advantage gained from carrying the image with him.

Test No. 2.—In the second test, the children were given pieces of paper on which were four right angles with sides respectively parallel and with convenient distances between them. (See Fig. 2, *a.*) This served as a device for the correct placing of characters. On a screen, 22 x 28 inches, was a similar figure and in each of the angles and spaces were

meaningless characters. (See Fig. 2, *b*.) These characters were used because they appealed to the eye and at the same time did not readily appeal to the auditory, motor and verbal memory. The screen was exposed five seconds, after which the pupils were to reproduce these characters, putting them in their proper place. In other words, the pupils were to make their paper look like the screen. The short time of exposure allowed very few to associate names with the characters, not more than one in five according to introspections that they gave in answer to questions concerning the naming of the characters. This test, on account of its simplicity and ease of grasp, was of especial value to the children of the lower

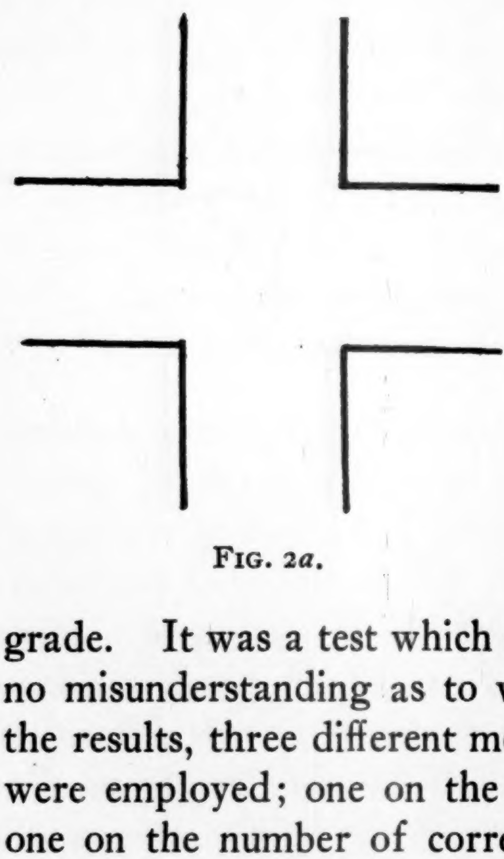


FIG. 2*a*.

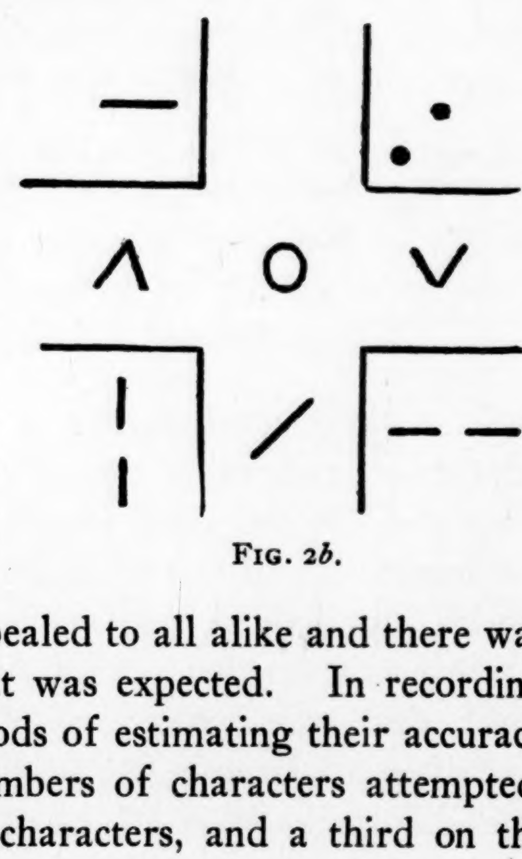


FIG. 2*b*.

grade. It was a test which appealed to all alike and there was no misunderstanding as to what was expected. In recording the results, three different methods of estimating their accuracy were employed; one on the numbers of characters attempted, one on the number of correct characters, and a third on the number correctly placed.

Test No. 3.—The third test of this group was similar to the second. The pupils were provided with papers ruled like the first. This time a screen was exposed which had letters and figures in the spaces instead of nonsense material. These characters were employed that all might have the use of sense symbols. These letters and figures were of different forms. Some letters were capitals, some were small, some were script

and some were printed. The figures were Roman and Arabic and all characters had a specific place. Ten seconds were given for observing, after which thirty seconds were given for reproduction.

This test, though more complex, was used as a complement to the second test. In the second test no one was supposed to name the characters, though there was nothing to prevent some name being attached to them. In this test, all the characters had names familiar to all. The letters were black, bold and of different size, while the angles were red, as was the case in the second test. The form and spatial relation were

FIG. 3.

the dominating elements considered. There were three grades given, one grade on the number of characters correct, one grade on the number of characters having the exact form in which they were written and a third grade on position. By a comparison of the results here obtained with those of the second test, a fair idea of a person's visual powers might be had.

In the second group of the series, four tests in number, nonsense syllables were used. The results of this group were quite satisfactory. The tests were clear, easily understood and but slightly different from the regular school work. The following are the tests of this group given in their respective order, but numbered as they occurred in the series.

Test No. 4.—Upon a piece of white cardboard, eight by

twenty inches, was placed, one above the other, a row of six nonsense syllables. These syllables were composed of three letters (two consonants and a vowel) and were made of black gummed letters, one and one-fourth inches high. The children were seated at their desks with pencil and paper. Upon a given signal the screen was exposed and twenty seconds were given to commit the syllables. At the close of twenty seconds the screen was removed and the children asked to write the syllables. As this was the first test with nonsense syllables, it was after a few moments repeated with different syllables, and the average of the two was taken as the initial test for the group.

Test No. 5.—In the fifth test a screen similar to the fourth was used but with different syllables. The only difference was in the manner of memorizing. As soon as the screen was exposed, the children took the blunt end of their pencils and wrote each syllable on their desk once. After this they were allowed the remainder of the twenty seconds to memorize the syllables as they chose. By comparing tests No. 4 and No. 5 some indication of the motor memory of the forearm was given, but not necessarily for other parts of the body.

Test No. 6.—After a rest from the first two tests, a third was given. The conditions were the same as in No. 4 and No. 5, and the same test was used only with different syllables. This test was to determine the value of the movements of the lips, tongue and throat, to the memory. In test No. 4, which was used as the standard, these organs were allowed absolute freedom in the process of memorizing. In test No. 6 these movements were impeded by catching the tongue between the teeth and holding it there during the test. Care was taken that the tongue was well extended and held both while learning and writing, so that there was little aid from this source. This method did not completely remove the motor sensations of the speech organs, but it did so impede them that any one strongly dependent on these sensations as an aid to memory could be readily detected. The results from this test compared with those of the initial test gave evidence of the extent to which the memory was aided by the sensations from the speech organs.

Test No. 7.—The seventh test was intended to appeal to the auditory type. While it is by no means certain that a person will employ auditory imagery in remembering syllables given in auditory presentation (it being quite possible for him to translate them directly into motor or visual symbols), it is fair to assume that the person who is distinctly of visual type will be somewhat at a disadvantage in remembering material thus presented. For persons of the motor type, the disadvantage will not be so great; still the distinctively auditory type should succeed better than the motor in such a test. The six nonsense syllables were used as before but this time were read and not exposed to vision. These syllables were pronounced and spelled slowly and distinctly to the pupils and then repeated. This took twenty second, the time of the other tests of this group of the series. At the close of the second reading the syllables were reproduced. Here the visual elements were at the minimum and the auditory at the maximum.

IV. The Test with Sense Material.

The series of tests described above dealt largely with material without meaning. The matter of interest was eliminated, and association was reduced in effectiveness. The test now to be described employed sense material appealing to interest and involving associations of considerable complexity. The purpose of this part of the investigation, as has been said above, was to discover, if possible, whether a given ideational type tends to retain better material suited particularly to this type, or whether the nature of the material is a matter of indifference. The test consisted of a story constructed with the purpose of appealing in its various parts to the three chief types of mental imagery (visual, auditory, motor). It was further constructed so as to gain as far as possible the attention and interest of the pupils of the various grades in which it was presented. This story was as follows:

Walter Brown, a young man who lives in Trenton, N. J., had an exciting time one night a few weeks ago.

A short time after he had gone to bed and when he was

A–1
just about falling asleep, he heard the (fire whistle blow loud
A–2
and sharp); then an (engine and hose cart came dashing over
A–3
the pavement) followed by a (crowd of shouting boys). Soon
A–4
it was (quiet again and for a time very still); then he heard
A–5
(the slow tramp, tramp, of the policeman) on the beat and
A–6
listened for the (ring of his club as he struck it against the iron
lamp post) at the corner. Mr. Brown was almost asleep again,
A–7
when he heard (the sharp clang of the motorman's bell) on the
A–8
street car next block; then the (big clock down town struck
A–9
with its deep tones). A minute later there came (a long, low
A–10 A–11
whistle), (a step on the porch), then (a gentle tap, tap, tap),
A–12
right under his window and then a (scraping sound) and (a
A–13 A–14
whisper) and (the noise of falling glass).

M–1 M–2
Mr. Brown slowly (raised himself in bed), (bent forward)
M–3 M–4
(and listened). Then (he carefully put one foot out of bed),
M–5 M–6
(held it a moment) and then (stepped softly on the floor).
V–1 M–7
(It was very dark), (and he felt his way with his hands
stretched out to the door of his room).

M–8 M–9
Then he (slowly crept down stairs), (holding his breath).
M–10 M–11
He (reached the lower hall) and (quickly turned the button)
V–2
that threw on the electric lights. In a moment (all the rooms

V–3
were lighted), and (he saw standing near the door of the
V–4 V–5
dining room) (a man with a red beard), (a black mask, partly
V–6
covering his face). The man (wore a blue coat), (and dark
V–7 V–8
trousers, spotted with mud). He had (a yellow cap on his
V–9
head), and (in his right hand he carried a revolver) (that
V–10 V–11
glistened in the light). (In his left hand he had a green
V–12
bag), and on (the side-board was a heap of silver spoons just
A–15
ready to be taken away). The burglar (gave a cry) and
V–13 V–14
(turned off the lights). (It was totally dark again). (Then
M–12 M–13
he sprang at Mr. Brown) and (pushed him to the door).
M–14
Mr. Brown (tried hard to keep from falling) and (held the
M–15 M–16
burgler tightly) around the waist. (Then he struck at him
A–16
with his fist), (and cried out help, help as loud as he could).
V–15
(Suddenly the lights were turned on again), and there were
V–16
(two policemen standing in the hall way with their revolvers pointed at the burglar). So Mr. Brown's midnight adventure ended and he escaped unharmed.

The parts of the story enclosed in parentheses are those portions or elements intended particularly to appeal to the three principal ideational types. Each parenthesis contains one such portion. The capital letters A, M, V, indicate respectively those portions appealing to auditory, motor and visual imagery, and the numerals after each letter show the number of these elements for each type. It will be noticed that there are sixteen for each type, forty-eight in all.

The results were estimated in terms of the retentivity of the

subject for each of these elements and they were then correlated with the results of the first set of tests in such a way as to show the retentivity of the visual type for the three kinds of material and in a like manner of the auditory and motor type of subjects.

The story was given to the subjects in auditory presentation. The test was carried out under conditions similar to those under which the first series of tests were conducted. It was in the same rooms with the same pupils and at the same time of day. The parts of the story appealing to different types were emphasized with equal prominence. No comment was made on the story and no explanation made. The pupils were told the story was to be read to them and after it was finished they were to reproduce it, telling everything that was in it.

Immediately after the story was read the pupils wrote it out on paper that had previously been provided them. The papers were collected, marked and filed. The next day at the same time, a second reproduction of the story was taken. There had been no previous warning that this was to take place, nor were there any suggestions given concerning the story. These papers were likewise filed for grading. Two weeks later, at the same time of the day, a third reproduction was taken in the same manner.

These papers were graded and the grades recorded in a manner similar to that used in the first series of tests. Each set of papers was graded separately and afterwards the papers were rearranged so that the papers from each person were together and the grades recorded. Each paper had three distinct grades, one for visual memory, one for auditory and one for motor.

V. Analysis of Results.

The following two tables give a summary of the classification of the various ideational types as obtained by the first series of tests:

TABLE I.

	3	4	5	6	7	8	H	U
Visual	72	67	59	49	47	42	46	50
Auditory	16	37	57	49	46	57	46	30
Motor	20	29	24	27	34	20	23	26
Balanced	20	20	10	21	19	24	28	20

TABLE II.

	3	4	5	6	7	8	H	U
Visual	58	51	45	24	26	23	31	45
Auditory...	11	11	40	36	34	32	31	18
Motor.......	11	18	5	19	21	21	10	17
Balanced ...	20	20	10	21	19	24	28	20

The above results were obtained by two different methods of classification of the data secured by the experiments. In the first table all subjects classed as partially visual, auditory or motor are represented under the appropriate type as indicated at the left. In the second table those classed as predominatingly of a particular type are classified under that type alone. For example a subject might be classed as visual-auditory. In the first table he would be represented in both the visual and the auditory columns, but in the second table he would be represented in the visual column alone. If the subject were on the other hand classed as auditory-visual, he would be recorded in the first table under both the auditory and visual groups; in the second table only under the auditory group. The numbers accompanying each group represent the per cent. of subjects classified under that group. Since in the first table a subject may be classified under two groups the total of each column is in every instance greater than 100. In the second table, since a single individual can be classified only under one group the total for each column is exactly 100. The numerals at the head of each column indicate the school grades from the third to the eighth inclusive. The letter H indicates the results for the high school students, and U the results for the university students.

By studying these two tables, the reader can see at a glance the preponderance of the visual type in the lower grades, and the gradual falling off of this type as the pupil advances in the grades, with a tendency to recover somewhat in the high school and university. The same fact is shown by another method of representing the results obtained in the first series of experiments.

These latter results are embodied in the curves of Fig. 4 found on page 104. These curves were obtained by plot-

ting the averages of correct results of the various tests in the first series, for the different grades and for the high school and the university. Curve *A* was obtained by averaging the results of tests No. 2 and No. 3, both of which were devised to test visual memory. Test No. 1 was not included in these averages because of the fact that the results were equivocal and on the whole unsatisfactory for most of the grades and particularly so for the university. Curve *B* em-

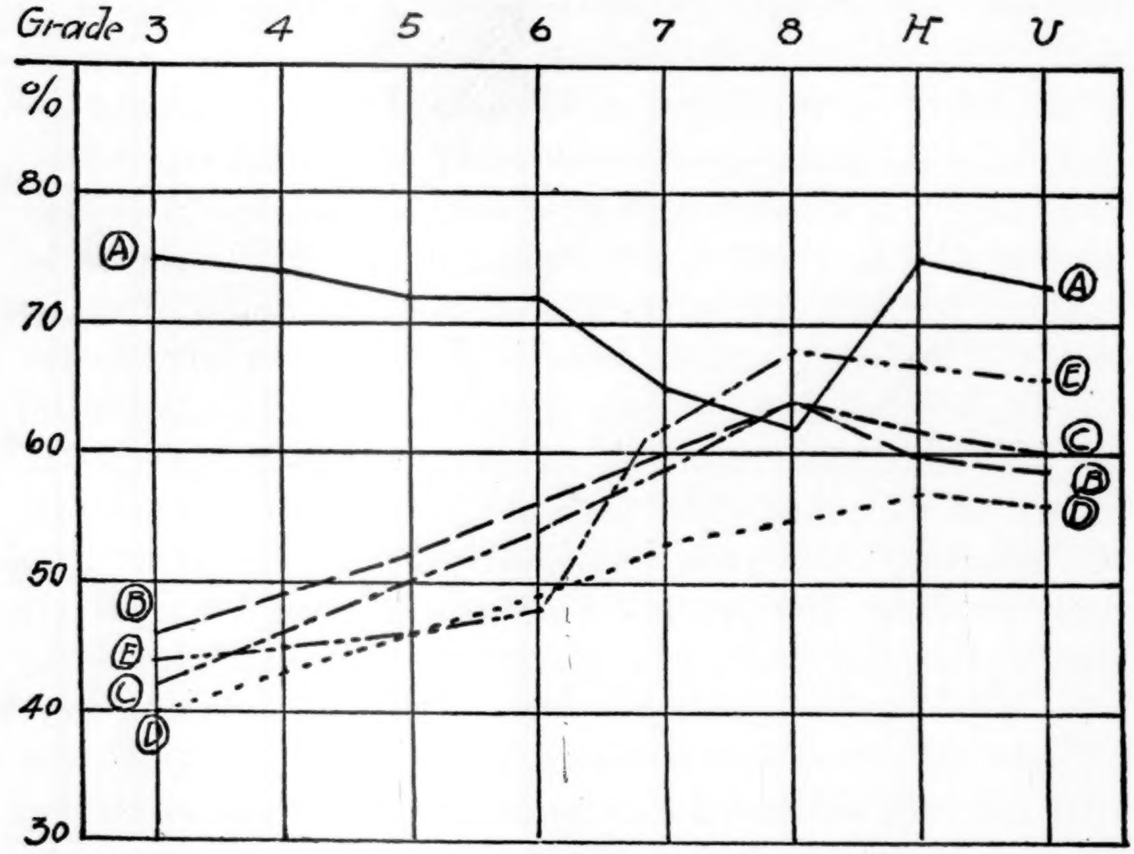


FIG. 4.

bodies the results of the test with the nonsense syllables visually presented; curve *C*, of the nonsense syllables visually presented and supplemented by tracing the syllables when exposed to view; curve *D*, of the nonsense syllables visually presented to the subject while he was inhibiting this tendency to vocalize by holding his tongue between his teeth, and curve *E*, of the nonsense syllables with auditory presentation.

It may be easily seen by this curve that the concrete visual imagery as indicated by the second and third tests is remarkably strong in the earlier years. In the third grade the pupils made an average of seventy-five per cent. of correct results with

these two tests; in the fourth grade of seventy-four; in the fifth of seventy-two; in the sixth grade of seventy-two; in the seventh of sixty-five; in the eighth of sixty-two; in the high school of seventy-five; and in the university of seventy-three. In other words, notwithstanding the fact that throughout the grades, the high school and the university, there is an ever-increasing ability to remember,[3] nevertheless the results of the third grade are higher in correctness than those of any other, with the single exception of the high school, in which an average of 75 per cent. of correctness was also obtained. The results of the tests in the university are two per cent. lower in correctness than those of the third grade for this test. These results clearly indicate an actual decline of concrete visual imagery during the school years.

On the other hand it appears from Fig. 4 that there is a fairly constant increase in verbal-visual memory throughout the years studied. This fact is particularly indicated by curve *B* (compiled from the results of the test with nonsense syllables visually presented). This curve begins in the third grade at 46 per cent. of correctness and rises in the main, being practically constant in the higher grades. In the lower grades it seems probable that a large part of the successful results with this test were obtained by the subjects holding a concrete visual image of the letters in their minds, while in the higher grades the *significance* of the syllables was the important element in retention. Undoubtedly here the visual imagery was assisted by the motor and auditory. The fact that the concrete visual imagery is strong in the lower grades and that there is a general tending toward the growth of a verbal type is also shown by certain facts noted incidentally during the course of the experiments.

In the earlier grades low averages were more often the result of the omission of characters than of an error in form or in place. In the higher grades, on the other hand, errors in form and place were more frequent, while omissions were far

[3] The results of Bolton, Bourdon, Hawkins, Winch, Binet and Henri, and others on the growth of memory in children have clearly established this fact. Meumann says that the adult learns various kinds of material in a much shorter time and with less repetitions and with less fatigue than do children. Young children, however, retain more exactly.

less. In these grades too an attempt was frequently made to assign names to the meaningless characters, a procedure reported less often in the lower grades. In the fourth grade thirteen per cent. of the pupils reported that they had attempted to name the characters, while in the seventh grade there were thirty-five out of a hundred that so reported. In the university it was the general procedure to assign some name to the characters, and to join the nonsense syllables together in some meaningful way.[4] It seems quite evident from these results that the undeveloped mind relies primarily on the impression for retaining its material while the more mature mind is greatly aided by holding the material through associations. Burnham, in his article on 'Retroactive Amnesia,' has pointed out the significance of the two elements in memory, the impression (*Einprägung*) and the association. The work of Müller and Pilzecker has clearly established the existence of the *Perseverationstendenz* as a factor in memory, and these results have been verified in other connections. This all goes to show that apart from the association of memory material by which it is retained and called up, there is also the factor of persistence that is due rather to the impression than the association. This sheer persistence seems to be a more important factor relatively in states of fatigue and mental disturbance than in normal conditions.[5]

It is likewise reasonable to assume that it is a more important element in the mind of the young child than in that of the more developed pupil. It is natural therefore to expect that concrete imagery will be more in evidence in the lower grades than in the higher, and since visual imagery is the most vivid and real of all imagery that it will be the predominating type among young children. This expectation the results of the present experiment seem to sustain.

The fact that mere impression is a more important element in the recall of young children than of older is further shown by the fact that where the nonsense element is the most marked

[4] An analysis of results seem to indicate that ninety per cent. of the university students did this to a greater or less extent.

[5] Heilbronner and Stransky working on abnormal subjects both assert that 'perseveration' is something that forces itself into the regular train of association, and it to be treated as an accident (*Ausfallerscheinung*).

(namely in tests No. 2 and No. 3) there is, as has been pointed out, an actual decline in correctness. This is not the case with the tests involving the nonsense syllables which permit a certain amount of association. Tests Nos. 4, 5, 6 and 7 all show some, though not great improvement in correctness as the age of the pupils increases.

Further, the steady increase of memory throughout the grades for visual auditory and motor material alike, when this material is connected in meaningful associations is shown in the results with the story. (See Figs. 5 and 6, page 109.) Here there is an increase in the per cent. of correctness in immediate recall for the visual elements of the story from twenty-four per cent. in the third grade, to seventy-four per cent. in the university; in the auditory element from twenty-three to sixty-nine per cent., and in the motor from forty-seven to sixty-eight per cent. The corresponding figures for the recall one day later (Fig. 6) are: Visual imagery, for the third grade twenty-four per cent., for the university seventy-four per cent.; auditory imagery, for the third grade twenty-two per cent., for the university sixty-six per cent.; motor imagery, for the third grade forty-four per cent., for the university seventy per cent.[6]

The marked decline of curve *A* representing the results of tests No. 2 and No. 3 in the seventh and eighth grades and its recovery in the high school and university is possibly to be explained as follows:

The chief element in the retention of the younger children is the impression represented by the concrete visual image; of the more mature child and the adult, the association. The rapid decline of the concrete image is not compensated for by a corresponding increase of the element of association until the high school and the university are reached. There is, therefore, an actual decline in memory for concrete visual material at about the onset of puberty. This decline has already been pointed out, as before stated, by previous investigators.

If we turn again to the tables on pages 102 and 103, we will notice the growing importance of auditory imagery as

[6] The preponderance of the motor element of the story in the recall in the lower grades is not out of harmony with the seemingly contradictory results obtained with the nonsense material. Its meaning will be discussed later.

determined by test No. 7. This test shows the relatively slight importance of this type of imagery in the lower grades and its growth in the last four years of the grammar grades. A somewhat similar development is shown by curve *E*, of Fig. 4. Here, however, the pronounced development of the auditory type is indicated as first manifesting itself in the seventh and eighth grades. How much the increase represented in the tables and in the rise of curve *E*, is due to a change in ideational type and how much of it is due to the fact that auditory presentation is more favorable for learning in the higher than in the lower grades is, however, a question.[7]

[7] A number of investigators have attempted to determine which mode of presentation (visual or auditory) gives the better result in the recall of the material presented. Hawkins, who presented visual and auditory words at the same rate to his subjects, concluded that auditory presentation was superior for children; visual for adults. Kirkpatrick found younger pupils superior in memory of spoken words. On the other hand, Miss Calkins found visual presentation superior to auditory. MacDougall, using nonsense syllables, agrees in this. Whitehead, also using nonsense syllables with adults, found visual presentation better. The most enlightening results in this field are by Pohlmann who found acoustic presentation better for significant material, visual for nonsense material. The fact is of special importance in connection with the results of test no. 7, which has to do with nonsense syllables. In the lower grades the nonsense syllables cannot be imaged well when pronounced to the pupils because they are unfamiliar. In the higher grades this significance can more readily be comprehended and therefore they do not put the older pupil to the disadvantage under which the younger suffers.

In this connection it may be well to point out the probable reason why the younger pupil more readily retains material that has meaning when presented in an auditory manner than in a visual. It is not because the younger pupil is of a less pronounced visual type than is the older pupil. Indeed the results of this and other studies show the reverse to be true. It is rather because auditory presentation is of necessity successive and visual generally simultaneous that the superiority of the auditory over the visual is shown. The young pupil attends better when he gives successive attention to the material presented in an auditory manner than he does to the visual material over which his eye may move at will and without plan. If he is visual minded the material presented in an auditory manner is quickly (for the most part unconsciously) translated into visual terms and what is lost in this translation is more than compensated for by the more effective attention secured through the successive presentation when the material is read to the pupil. With nonsense material, however, the visual presentation is a tremendous advantage in the earlier grades over the auditory presentation and the gain in successive auditory presentation is more than counterbalanced by the loss which the pupil suffers in not being able to form a distinct image of the spoken nonsense syllable.

It is probable that both the manner of the presentation and the type of the pupil are factors in the general result. Some further light is thrown upon this question when we examine the curves in Figs. 5 and 6. These curves, as has been previously stated, give the general results of correctness in the reproduction of the three different elements of the story. Here

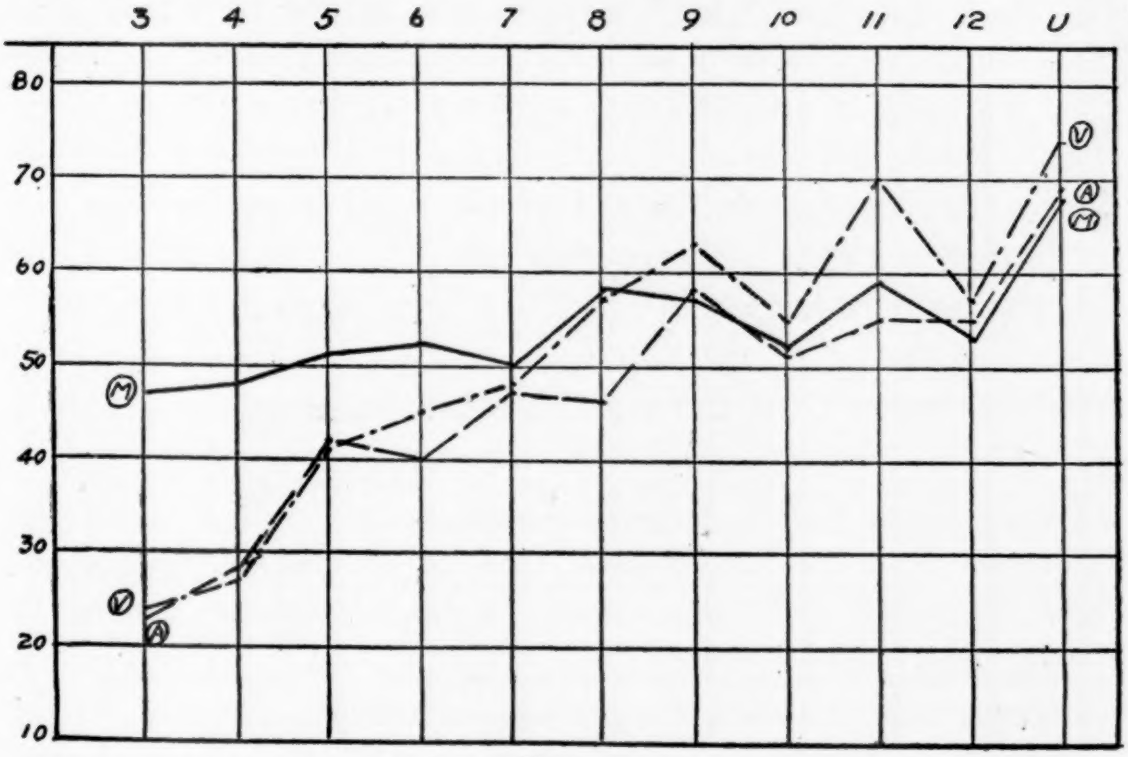


FIG. 5.

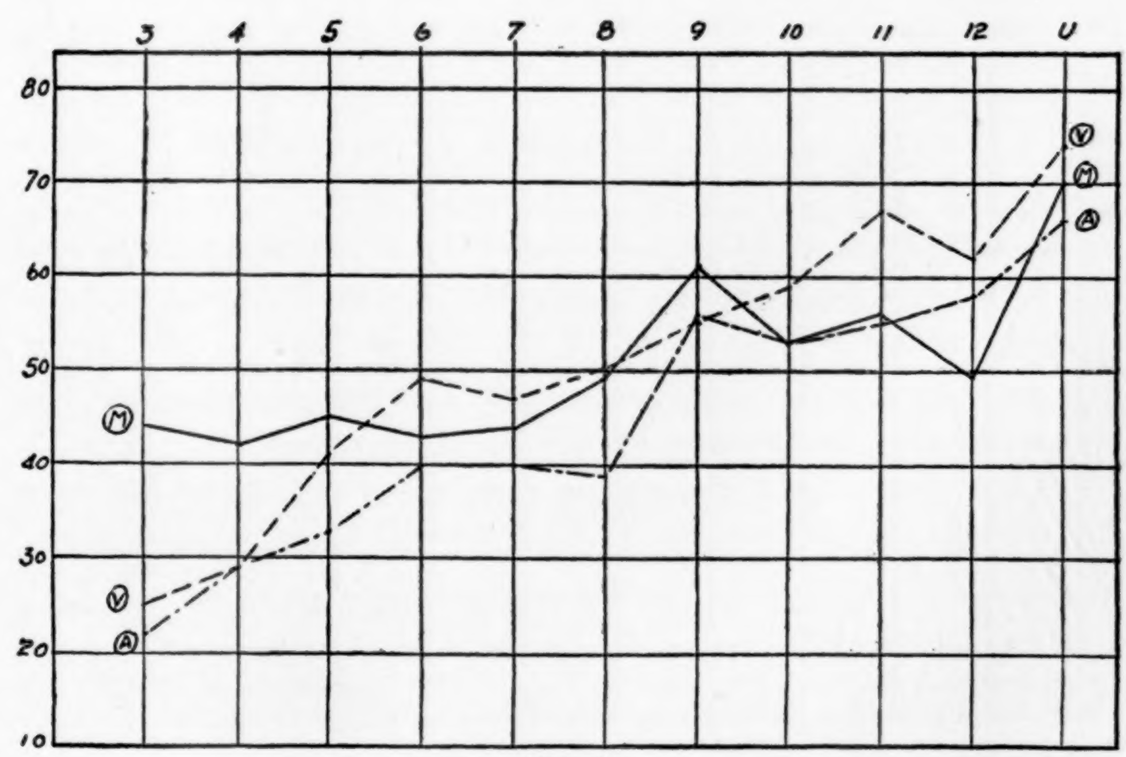


FIG. 6.

the manner of presentation is a negligible factor since it is throughout auditory. From these curves it will be seen that the auditory element is in general inferior to the visual.

On the whole it seems reasonable to conclude that the auditory type approaches maturity later in life than does the visual and it is probably much more closely associated with the motor, which as can be seen by the tables and by the curves of Fig. 4, is in general inferior to both visual and auditory. Probably both motor and auditory imagery are more closely allied with verbal imagery. There seems less tendency for the motor type to grow as the age of the pupil increases than for the auditory type. The curves of Fig. 4 show the slight importance of this type in recall. Curve *B*, as has been said, gives the results of the test with visually presented nonsense syllables; curve *C* of the visually presented nonsense syllables when the learning was accompanied by tracing the syllables seen, with the blunt end of the pencil, and curve *D* of the visually presented syllables learned and reproduced with the tongue between the teeth. It is a surprising result that the tracing is not an aid to the learning in the earlier grades. Indeed it is a hindrance until the eighth grade is reached. This is to be explained by the fact that the movements are an actual distraction and that the motor imagery is of so slight importance that the distraction is more of a hindrance to learning than the motor imagery is an aid. The relatively slight importance of the motor imagery of the speech organs is shown by curve *D*. While this curve is lower than curves *B* and *C* the difference is not great, and that difference may probably be attributed more to distraction than to dependence on motor imagery. It is slightly more pronounced in the upper than in the lower grades, however. This may indicate the increase of the 'inner-speech' as the age of the pupil increases.

The results from the motor tests were strikingly different from what might be expected from children in the lower grades. In the tests at this period action was strongly manifest. There was scarcely a child that did not move his lips and movements of the entire body were not infrequent, especially when interest was great.

In the fourth, fifth and sixth grades, especially in the last two, there seems a strong tendency for the child to attempt to employ his motor impressions to assist in memory. To do this he does not depend much on particular muscle sensations, but all the body seems to be active. When intensely interested he moves his arms, twists in his seat, strikes his fist into the palm of his hand, shifts his feet and goes through a variety of other movements, but does not use his pencil. No doubt he tries to bring these movements, in a general way, into coördination with his visual powers, but only in the most indefinite way. The muscles of the fingers are not used, as in the higher grades. It is quite probable, however, that if all the random movements had a direct bearing on the material in hand they would be of much value, but they are too general to be effective to any great extent.

In all the grades below the high school the lips were almost invariably used in memorizing syllables. So conspicuous and so common is this practice that it has been urged by educators, that lip movements should not be inhibited during study. Not ten per cent. of the pupils in the grades kept their lips motionless in the course of a test with syllables. Yet the actual assistance received from the motor sensations in the early period is not great. It is often over-estimated. It is probable that the motor impressions are not used during this period as an aid to memory. While the child moves much, the movements are not such as to be of value to the memory process. The child writes comparatively little before the sixth grade, and the use of the lips as a means of fixing impressions on the mind is probably more or less automatic. Other motor responses accompanying the learning process are general in character and so many and so diverse that the mind loses sight of them as a means of assistance. About the sixth grade, or seventh grade, writing becomes of much more importance as an aid to memory.

There seems to be some difference of opinion among investigators in regard to the value of motor aids in memorizing. Lay concludes from his experiments with children, to whom he presented both visually and orally nonsense words under

different conditions, that these aids are important. Itschner, who repeated Lay's experiments under more careful conditions, does not agree that the favorable effect of writing the words presented is due to the motor processes, but to factors of greater attention, etc., accompanying this procedure. Fuchs and Haggenmüller who worked with unfamliar Latin and German words, found on the whole that learning without vocalization or in a whisper was superior to pronouncing aloud. Writing in the air was a great hindrance, while copying and pronouncing in a whisper was an even greater distraction. Pohlmann says that the addition of the motor element is not favorable to memorizing. Miss Métral, in a recent study with boys and girls from seven to nine years, concludes that speech and arm-motor aids are valuable in learning to spell. The studies of Smith, of Cohn and of Fränkl also seem to indicate the value of motor aids in memorizing. (For reference to these three last named investigators see the bibliography at the conclusion of the fourth study in this monograph. The results of Lay, Itschner, Fuchs and Haggenmüller are discussed at some length in this latter study.)

The results discussed above show the way in which the mind develops rather than the cause for the particular tendencies in this development. Evidences are not lacking, however, to show that training[8] has much to do with the development of particular types of mind.

In the third and fourth grades the types were more distinctly marked. There were much wider individual differences in the results of tests. In these lower grades there is extreme variety in results, which is not so marked in the higher grades. While vision holds the predominance over other types, yet it was not an infrequent occurrence to find a person who showed

[8] In this connection the discussion of Segal in regard to memory types should be mentioned. He contends that these types are not so fixed and characteristic as the work of Charcot and other later investigators might lead us to suppose. The particular type that an individual possesses for a certain class of objects depends largely on the customary nature of the presentation of that class of objects; and it is not to be wondered at that the visual type is predominant when we remember that most of the objects to which we attend and which are of importance for us, come through visual sensations.

very strong auditory-motor type with poor visual powers. The circumstance that the visual power in general is strong at first is due to its being the first type of imagery to be effectively used and in the earlier years it is constantly being developed. In these early stages vision seems the natural avenue for gathering information and in this it has the advantage in the outset, which is shown in the first years of school life. From the fourth grade on to the eighth there is a growing tendency toward what might be called a balanced type in which the three types are more on a level.

As the pupil advances in the grades his attention is more and more taken from concrete visual objects and centered on reading and writing,[9] the auditory and motor sides thus being especially emphasized.

Before passing on from this part of the investigation, it may be worth while for us to consider a seemingly surprising fact that came out incidentally in connection with certain results, and which, while not being an integral part of the experiment itself, has an important bearing on the general problem of the psychology and pedagogy of learning.

During the course of the first part of the experiments in several instances, the tests with the nonsense syllables were repeated twenty-four hours later with the result that only a very slight falling off in the recall over the previous day was indicated. As this result was obtained toward the close of the series and as time did not permit an extension of this aspect of the experiment, not a sufficient amount of data was obtained in this connection to make any extensive generalizations.[10] The results of the second part of the experiment (the test with the story) were, however, even more striking in this particular and showed clearly that there was practically no loss in the recall twenty-four hours after, as compared with the immediate

[9] An extensive series of experiments recently concluded in the Urbana, Illinois, schools, show that the process of writing is not fully mechanized before the seventh or eighth grade.

[10] In the Urbana tests referred to above, and which were made with series of nonsense syllables, the average for the five upper grammar grades was as follows: Immediate recall (three different series of tests, 61.55 per cent.; 48.6 per cent.; 48.3. Recall after one hour, 56.9; 46.1; 50.1.

recall. By comparing Figs. No. 5 and No. 6, the reader can see that the falling off in memory after twenty-four hours is extremely slight. This fact can perhaps be better seen by glancing at the following table in which the figures at the left in each column indicate the per cent. of correctness for each grade in immediate recall of the story, and the figures at the right the per cent. of correctness for the recall twenty-four hours later.

	3	4	5	6	7	8	9	10	11	12	U
Visual Elements	24–25	27–29	41–41	45–49	48–47	57–50	63–55	55–59	70–67	57–62	74–74
Auditory Elements	23–22	28–29	42–33	40–40	47–40	46–39	58–56	51–53	55–55	55–58	69–66
Motor Elements	47–44	48–42	51–45	52–43	50–44	58–49	57–61	52–53	59–56	53–49	68–70

It can be seen from an inspection of this table that in the third and fourth grades the per cent. of correctness for recall after twenty-four hours is practically as high as that for immediate recall. This is likewise true of the high school (grades nine, ten, eleven and twelve) and for the university. Grades five and six show a somewhat more marked falling off in correctness after twenty-four hours than do grades three and four, and in the seventh and the eighth grades this difference is quite pronounced. The fact that the loss is the greatest at this latter period may possibly be explained in the same way as the decline in curve *A* (shown in Fig. 4, and representing tests No. 2 and No. 3 in the first series) was explained, namely, by the fact that the concrete imagery which is strong with young children, has become weakened in the latter years of the grammar grades, and that power of association has not at this time sufficiently developed to make good the loss of the concrete imagery. This slight falling off in the curve of forgetting after a period of twenty-four hours when a much greater decline would have been expected, has been noted by several investigators.

It will be recalled that Ebbinghaus in his pioneer experiments with nonsense syllables found that, tested by the *Ersparnismethode,* the rate of forgetting was proportional to the logarithm of the time. These results were later confirmed

in the recall of tones by Wolfe and others. On the other hand Boldt, in an experiment with thirteen normal and thirty-five pathological subjects, found that for the former an increase of the interval between the presentation and the recall resulted in an increasing accuracy. Reproduction after five minutes was not as good as after fifteen, and the best results of all were obtained after twenty-four hours. The fact that these results held good for normal subjects and not for those suffering from mental disease is significant and will be referred to again.

Lobsien likewise found in experimenting with twelve pictured objects that the repetition of the test without intervening recall indicated that memory in children increased in accuracy for from one to two days, and Binet reports that many scholars, eight days after learning, remembered more than immediately after. Experimenting with smaller intervals, Finzi found that the best reproduction does not come immediately after presentation, but somewhat later (from six to thirty seconds).

The explanation offered by Watt in commenting on Lobsien's experiment, that the children talked the matter over in the meantime, may in part explain some of these seemingly strange results, but is hardly sufficient to account for them as a whole.[11]

The discrepancy between the results of the present experiment and those of Ebbinghaus and of Wolfe may in part be explained by the fact that a different method of testing the recall was used by Ebbinghaus and by Wolfe than by the writers of the present paper. Ebbinghaus used the *Ersparnismethode,* as previously stated, and Wolfe the method of identification, while in the present experiment memory was tested by the amount retained in the recall. These differences in the method of testing the memory are not, however, sufficient to explain the great difference in the results. Ebbinghaus used nonsense syllables, Wolfe tones, while in the present experiment sense material (the story) was employed as a test for delayed recall in most instances, although as previously stated, a few results were taken with nonsense syllables.

[11] The tests in the Urbana schools were so conducted that the delayed recall excluded the possibility of communication in most cases.

The most reasonable explanation for the difference of the results in the experiments of Ebbinghaus and of Wolfe and in those of the present investigation is to be found in a fact already discussed, namely, that two factors are necessary for effective recall, namely, the impression and the association. The tones used by Wolfe offered but few opportunities for association and hence the chief means of recall was through the impression, which was probably not particularly vivid, especially for adults who had lost to a great extent their power of concrete imagery, if indeed, they had ever possessed it, for tones. Naturally then, there would be a somewhat rapid falling off in memory under such conditions. Ebbinghaus used himself as observer in his test with nonsense syllables. These he had trained himself to learn without bringing in tricks of association, something which the untrained observer has a constant tendency to employ. Ebbinghaus must, therefore, have relied largely in recall upon the impression and not on the association. Hence came the rapid falling off in the memory curve. Both with nonsense syllables and with the story in the present experiment there was doubtless a large rôle played by association in the recall, and as Dr. Burnham has pointed out in his article (previously cited in this paper) association requires some time to fix itself. Hence the length of the interval was an important factor in the accuracy of recall. In this connection the results of Boldt may again be cited. He found with normal subjects that an interval between learning and recall strengthened the memory, but this was not true with pathological subjects, whose associative processes were much weaker than those of the normal subjects. The pathological subjects were not able to retain the material presented, because they could not associate it. Goldstein, working also with pathological subjects, found a marked distinction between the *Einprägung* and the association. The subject might be successful in immediate recall, while showing great weakness in delayed recall.

It must be remembered that in the case of young children, while the associative element is not so important in recall as with the adult, the impression of the sense material is doubtless much stronger, and it is preserved in concrete visual imagery

for some time. It, therefore, does not fade from the mind as rapidly as the same sort of an impression would fade from the mind of an adult who has lost his power of concrete imagery to a great extent. For these reasons it is hardly to be expected that the memory curve of Ebbinghaus would hold good under the conditions of the present experiment, either for the child who relies largely on the vividness of the impression, or for the young person and adult who rely much more on association. Granted that the results of the present experiment are valid in the point now under discussion, these results by no means disprove those of Ebbinghaus; they do, however, indicate that his results have a much more limited application than has generally been supposed, and that they are not valid in general for learning under the usual conditions of the school.

These results suggested a parallel between the growth of memory and the acquisition of a skilful act by an individual. The study of Bryan and Harter in the learning of the telegraphic language, and other studies later made along similar lines, have shown the fact that plateaus develop at certain stages of the process of acquisition, and the individual must wait for a new set of coördinations to be perfected before an advance to a higher level can be made. It is true that here there is not actual loss, as there is when the concrete imagery becomes weakened in the child's mental development. On the other hand both in the development of memory and in the perfection of a skillful act an advance is conditioned on the perfection of new powers as yet imperfectly under control.[12]

The last part of this discussion brings us to the question of the relation between the various memory types and the learning of materials appealing to the different sense departments. As has already been said, but little attention has been paid to this problem by investigators. The work of Segal, which bears

[12] In this connection my colleague, Dr. J. W. Baird, suggests an interesting fact in the learning of the game of billiards. He informs me that the first shots made by beginners are the more simple carrom shots. Later when the cushion shots are tried, the ability to make the carrom falls off, and the novice, who has not as yet perfected his cushion shot sufficiently to make it of any great value to him, actually falls off in his play for the time. Thus there is a decline in the curve of efficiency.

somewhat directly on the subject here under discussion, has already been mentioned. Meumann agrees with Segal, that it is advantageous to fit the material presented to the ideational type of the learner, and not as Münsterberg and Bigham maintain, present the material through all possible avenues. In

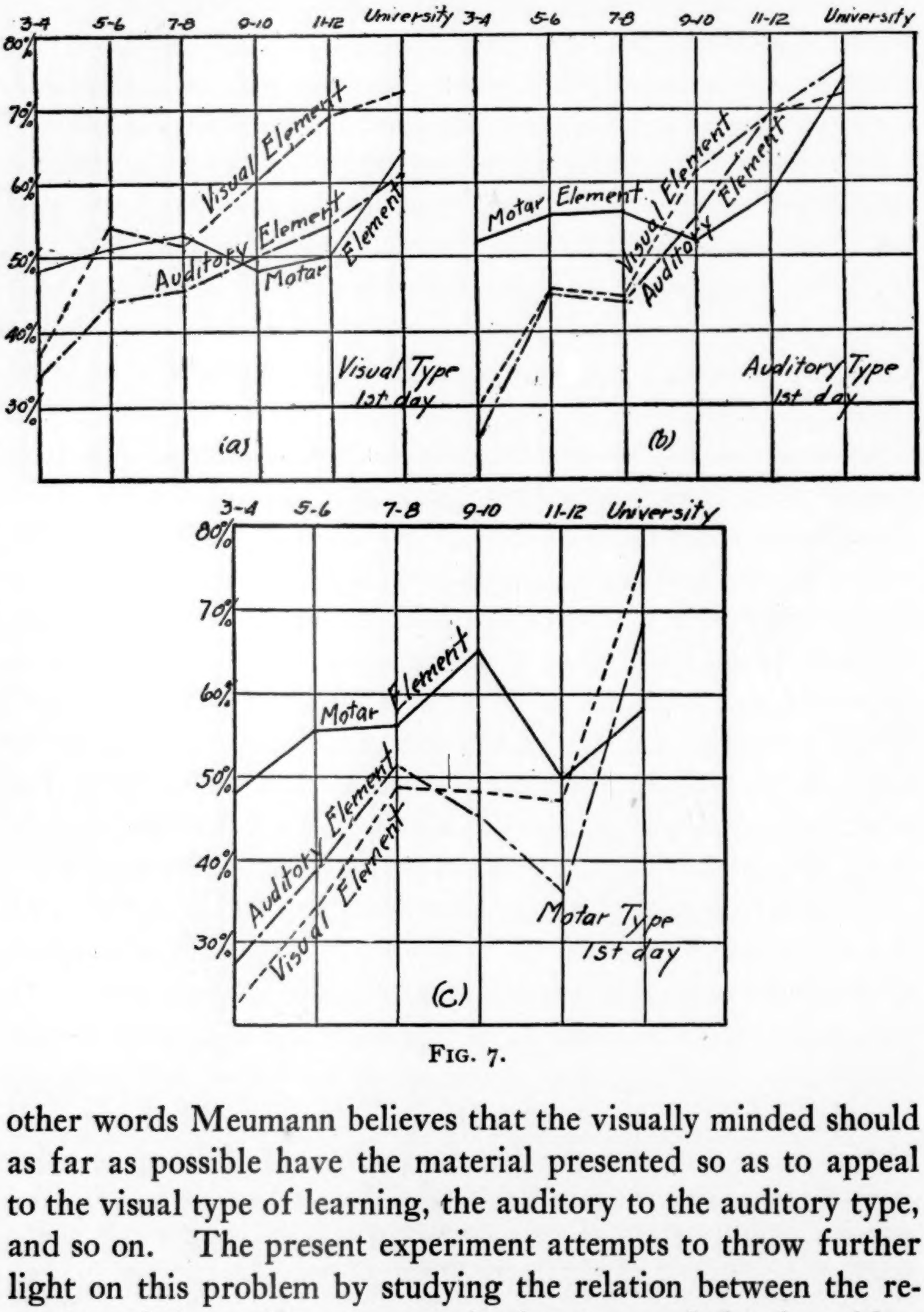


FIG. 7.

other words Meumann believes that the visually minded should as far as possible have the material presented so as to appeal to the visual type of learning, the auditory to the auditory type, and so on. The present experiment attempts to throw further light on this problem by studying the relation between the retention of the various elements in the story and the three idea-

tional types, as determined by the first series of tests with nonsense characters and syllables.

By means of these first tests all the subjects studied, as has been explained above, were classed under one or more of the three ideational types. In the test with the story the retentivity

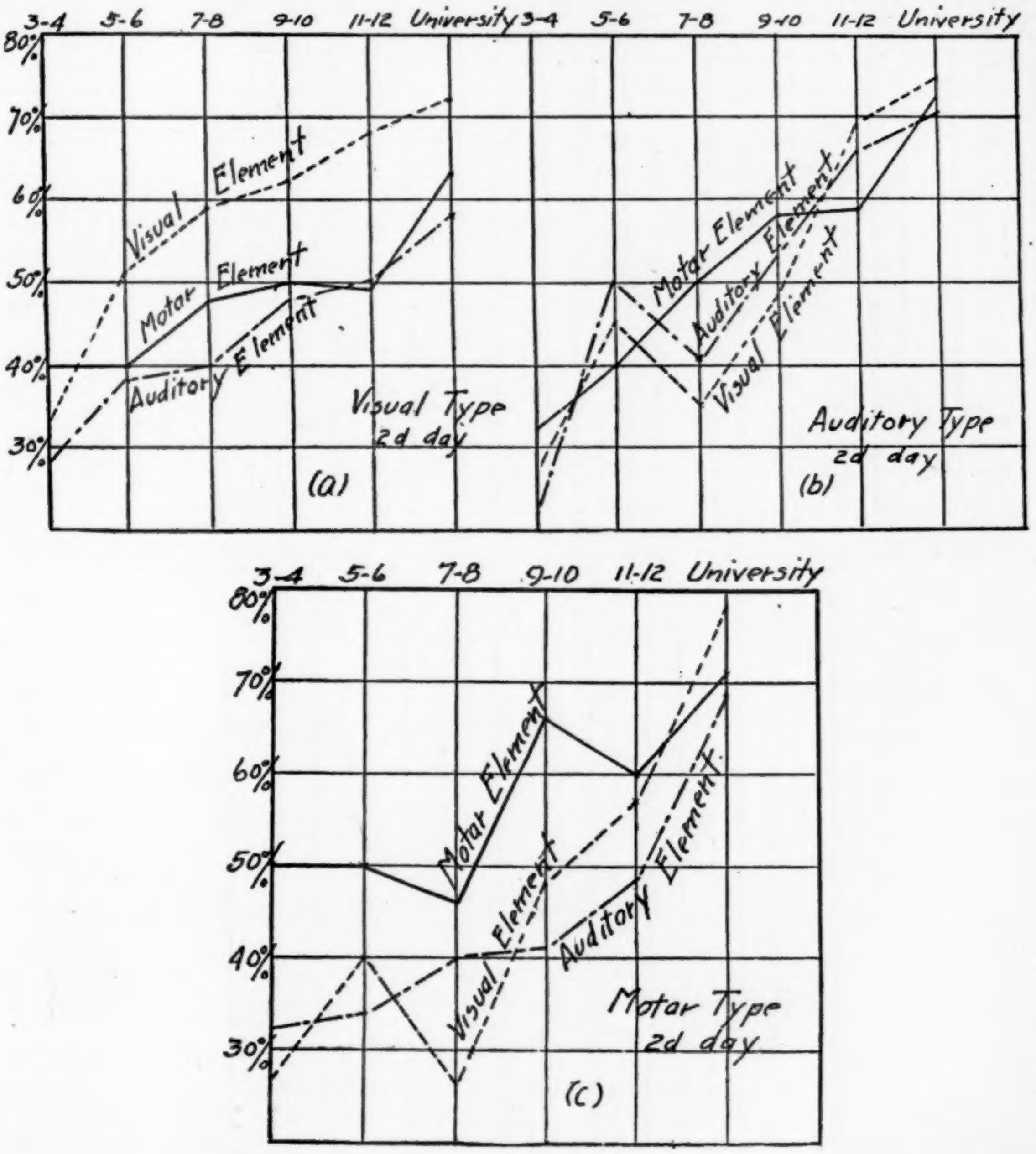


FIG. 8.

of all the subjects of each type for the three different elements of the story was determined. The visually minded subjects were studied for their memory for the visual, auditory and motor elements in the story; the auditory and the motor minded subjects were also considered from a like standpoint. The results of this tabulation are expressed graphically in Figs.

7, 8 and 9. Since the classification into visual, auditory and motor types separated each school grade into three groups, and these generally of unequal size, varying as the particular grade under consideration was strongly of one type or of another, some groups were small. For this reason, in

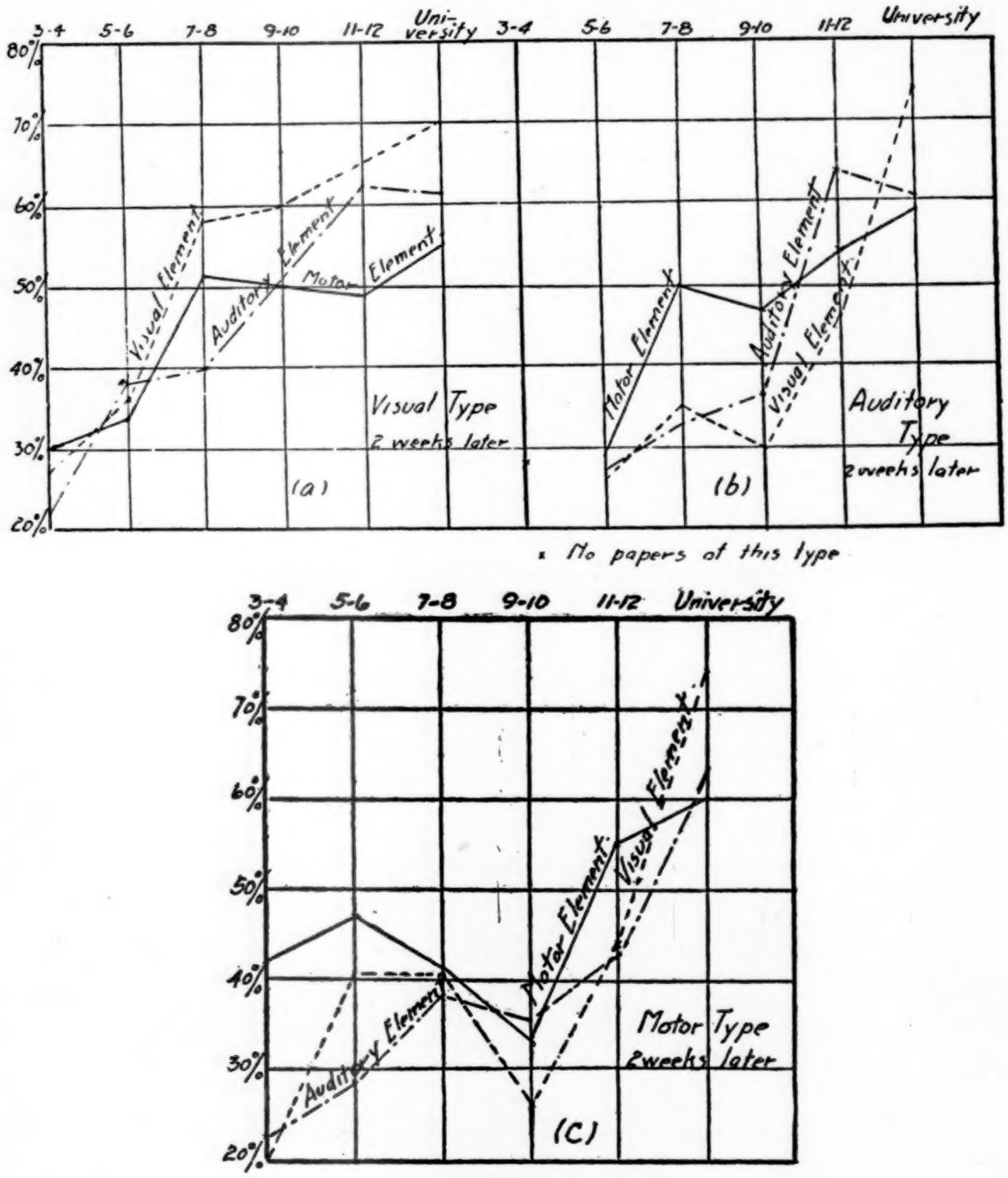


FIG. 9.

the tabulation of the results two grades were combined and the data of the third and the fourth, the fifth and the sixth, and the seventh and the eighth grades were averaged together. The curves represent the results for immediate recall, for recall after an interval of twenty-four hours, and for recall

after an interval of two weeks. These last named were not as satisfactory as those taken immediately after the reading of the story, or after a lapse of one day, since in some of the grades and in the high school especially, pupils were being examined at the end of the semester's work. This circumstance will explain some of the variations in the results recorded in Fig. 9.

The portions of Figs. 7, 8 and 9 marked (*a*), indicate the manner in which the visually minded subject recalled material appealing to the three sense departments (visual, auditory, motor); the portions marked (*b*) indicate the same for the auditory type, and the portions marked (*c*) for the motor type. Fig. 7 gives the results for immediate recall, Fig. 8 for recall after twenty-four hours and Fig. 9 after two weeks.

It can be seen at a glance that for the early grades the motor elements in the story are better retained than are the visual or auditory. This is true for the three ideational types, both in immediate and in delayed recall. On the other hand, the test with university students shows the superiority of the visual elements, with but one exception for all types, both for immediate and for delayed recall. The superiority of the motor elements of the story in the lower grades is to be explained doubtless in terms of attention and of interest. The narration of what was done by Mr. Jones and the other characters is the most vivid part of the story. It has been pointed out by several investigators that the securing of interest is one of the chief factors in the instruction of young children. This is the all-important thing in the earlier stages of development. By the time the university is reached, however, the mere matter of interest in the story has become much less important, and the tendency towards verbal-visual imagery strongly asserts itself.

Apart from the striking importance of the motor elements of the story in the earlier grades, it will be found in general that the visual elements of the narrative are best retained by the visual type both in immediate and in delayed recall, though the visual elements show their superiority more in delayed than they do in immediate recall, more particularly in the recall after twenty-four hours. The auditory elements are not, how-

ever, as well retained by the auditory type as are the motor elements except in the case of the higher grades and the university, and in many instances the visual elements show superiority over the auditory for the auditory type. It can, however, be seen that the auditory type in general retains auditory elements better than does the visual or the motor types. The motor type is at a very distinct advantage in retaining motor material over the visual type except in the university, and in general shows a superiority, though not so pronounced, over the auditory type, particularly for immediate recall and for recall after twenty-four hours. On the other hand both the auditory and the visual type retain motor material as well on the whole as does the motor type when the recall is delayed for two weeks. The curves seem to indicate in general that the visual type possesses a superior retentivity in delayed recall as compared with the motor type, and to an extent as compared with the auditory type. This circumstance tends to confirm in general Meumann's contention that the visual type has greater powers of retentivity than have either the auditory or the motor types. Finally it may be said that in general the visual ideational type is best suited to learn and retain material with a visual content, except in such instances as when material with a motor content appeals so strongly to the interests (particularly of young children) as to gain and hold the attention.[13] The auditory type on the whole and particularly in the lower grades, does not learn and retain material with an auditory content as well as with a motor content, though as a rule visual material is inferior to auditory, particularly in delayed recall. The motor type retains motor material better than it does visual or auditory except in the higher grades. It seems not an unwarranted conclusion (when the element of superior interest

[13] The factor of interest in movement may explain the results of Colvin and Meyer in the study cited above. Throughout the grades the boys found it their most powerful for of imagery. The girls also showed a highly developed motor imagination. For the boys words with a motor content predominated up to the high school, and for the girls the motor images were in excess of the visual up to the same period. In the grades words denoting both visual and auditory content are markedly lower than the words denoting a motor content, in the case of the boys.

in the motor material is removed) that each type of ideation is best suited to learn and retain material appealing to the particular sense department to which this type belongs. An exception to this is to be noted, however, in the higher grades and the university where visual material sems to be better learned and retained by all three types. Here doubtless the auditory and motor types rapidly and with practically no loss translate the material from one sense department to another. This can be readily done since concrete imagery has greatly fallen off and symbolic and verbal thinking has taken its place, a type of thinking to which visual imagery particularly lends itself.

VI. Summary and Conclusions.

The results of the above experiments may be summarized as follows:

1. It seems to be established beyond reasonable doubt that the young child thinks largely in concrete visual imagery, and that while auditory and motor imagery are present to some degree, they play a relatively unimportant rôle in the lower school grades. The child up to ten at least is predominantly a visualizer.

2. Concrete visual imagery, and probably all concrete imagery, tends to fall off in the more advanced grades, its place being taken by verbal imagery. The rise of the latter is probably closely connected with increase in ability to associate and to give meaning to memory material. This ability, however, at first does not compensate for the actual loss in vividness of the concrete imagery, hence there seems to be an actual decline in imagery about the onset of puberty. The subsequent recovery and advance is not due, however, to the recovery of concrete imagery, but to the growth of a power on the part of the adolescent to associate and group into meaningful relations his memory materials. The loss of concrete imagery should be taken into consideration in the schools, and while the pupils should be trained to associate and relate their materials, they should still be educated in such a way as to preserve their ability to think in concrete imagery when such thinking is de-

sirable; and this all the more because it is quite probable that most persons are not by nature predetermined to belong to a particular ideational type. Education has much to do in determining particular types and it is quite possible for a person to think in terms of verbal and symbolic imagery for one purpose and in terms of concrete imagery for another.

3. The importance of motor imagery, both for the hand and for the vocal organs, appears to be much less than has generally been supposed. Doubtless many have confused the interest that children have in movement with an ability or tendency on their part to think in motor terms. Except in pronounced cases where the child is extremely motor in his way of thinking, children seem to depend but little on their motor imagery; indeed, the kinæsthetic sensations from throat and hand may be a hindrance rather than an aid in learning.

4. Auditory imagery shows growth in the period of later childhood. It may, however, be doubted that there is any growth in concrete auditory imagery, which probably is not at any period of development nearly as important as concrete visual imagery. The growth of auditory imagery probably indicates the increase of the verbal type of imagery and its development may show the growing tendency to think in terms of the 'inner-speech.'

5. The rapid falling off of the memory curve as established by Ebbinghaus and confirmed by subsequent experiments does not seem to hold good in the present experiment. Recall after twenty-four hours seems to be as good on the whole as immediate recall, when tested by the method of parts retained, as was the case in the present experiment. This fact is extremely significant in the psychology of learning, and seems to be in harmony with the point of view of Dr. Burnham and the results of several recent investigators.

6. There seems to be a fairly definite relation between the effectiveness of memory in the case of a particular ideational type and the memory material which is most suited to that type. In particular the visual type retains best material with a visual content and the auditory and motor types, to a less degree, material with an auditory or motor content, as the case may be.

Bibliography.

Bigham, J. Memory. Psychol. Rev., I., 34–39, 453–462 (1894).

Boldt, K. Studien über Merkdefekte. *Monatssch. f. Psychiatrie u. Neurol.*, XVII., 97–114 (1905).

Burnham, W. H. Retroactive Amnesia: Illustrative Cases and a Tentative Explanation. *Amer. J. of Psychol.*, XIV., 382–396 (1903).

Calkins, Mary W. Short Studies in Memory and in Association from the Wellesley College Laboratory. Psychol. Rev., V., 451–463 (1898).

Colvin, S. S., and Meyer, I. F. Imaginative Elements in the Written Work of School Children. *Ped. Sem.*, XIII., 82–93 (1906).

Ebbinghaus, H. Über das Gedächtnis. Leipzig, 1885.

Finzi, J. Zur Untersuchung der Auffassungsfähigkeit u. Merkfähigkeit. *Kraepelins Psychol. Arbeiten,* III., 289–384 (1901).

Fuchs, Heinrich, und Haggenmüller, August. Studien und Versuche über die Erlernung der Orthographie; veröffentlicht von Herman Schiller. *Samml. von Abh. a. d. Geb. der Päd. Psy. u. Physiol.*, II., 4, 63 (1898).

Goldstein, K. Merkfähigkeit, Gedächtnis u. Assoziation. *Zeit. f. Psychol. u. Phys. d. S.*, XLI., 38–47; 117–144 (1906).

Hawkins, C. J. Experiments on Memory Types. Psychol. Rev., IV., 289–294 (1897).

Heilbronner, K. Über Haftenbleiben u. Stereotypie. *Monatssch. f. Psychiat. u. Neurol.*, XVIII., Ergänzungb., 293–371 (1905).

Itschner, Hermann. Lay's Rechtschreib-Reform. *Jahrb. des Vereins f. wissens. Pädagogik,* XXXII., 206–234 (1900).

Kirkpatrick, E. A. Experimental Study of Memory. Psychol. Rev., I., 602–609 (1894).

Lay, W. A. Führer durch den Rechtschreib-Unterricht. Wiesbaden, 1899.

Lobsien, M. Über das Gedächtnis für bildlich dargestellte Dinge in seiner Abhängigkeit von der Zwischenzeit. *Beitr. z. Psychol. der Aussage,* II., 147–160 (1906).

MacDougall, R. Recognition and Recall. *J. of Philos., Psychol. and Sci. Methods,* I., 229–233 (1904).

Métral, M. La memoire de l'orthographe. *Arch. de psychol.*, VII., 152–159 (1907).

Meumann, E. Ökonomie und Technik des Gedächtnisses. Leipzig, 1908.

—— Vorlesungen, Leipzig, 1907.

MÜLLER U. PILZECKER. Exp. Beiträge zur Lehre vom Gedächtnis. *Zeitschr. f. Psychol. u. Phys. d. S. Ergänzungsband,* I. (1900).

PENTSCHEW, C. Untersuchungen zur Ökonomie u. Technik des Lernens. *Archiv f. d. ges. Psychol.,* I., 417–526 (1903).

PFEIFFER, L. Über Vorstellungstypen. Leipzig, 1907.

POHLMANN, A. Exp. Beiträge zur Lehre vom Gedächtnis. Berlin, 1906.

SEGAL, JACOB. Über den Reproduktionstypus und das Reproduzieren von Vorstellungen. *Archiv f. d. ges. Psychologie,* XII., 124–235 (1908).

STRANSKY, E. Über Sprachverwirrtheit. Beiträge zur Kenntnis derselben bei Geistes-Kranken u. Geistesgesunden. Halle, 1905.

WHITEHEAD, L. G. A Study of Visual and Aural Memory Processes. PSYCHOL. REV., III., 258–269 (1896).

WINCH, W. H. Immediate Memory in School Children. *The British Journal of Psychology,* I., 127–134 (1905).

WOLFE, H. K. Untersuchungen über das Tongedächtnis. *Wundts Philos. Studien,* III., 534–571 (1886).

ON THE ANALYSIS OF THE MEMORY CONSCIOUSNESS IN ORTHOGRAPHY.

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CONTENTS.

I. Nature and Aim of Study.

This study is one of a small class which attempts the investigation of a mental function just as it is found in life. In this respect it differs from most other memory studies whose chief aim has been the investigation of certain factors in or characteristics of memory without direct reference to where or how their influence is to be observed in the concrete ways of daily life activities. As one of the former class, it has to deal with a number and complex relationship of factors whose presence, nature and function it aims to determine. What are the mental processes involved in learning to spell an unfamiliar word, and what is the mechanism of their combined functioning? Some of those with which we are obviously concerned have received separate and special investigation in other memory studies. We know, for example, something

about the relative value for memory of visual and auditory methods of presenting verbal material, of the influence of vocalization and other motor processes when combined with visual or auditory perception. But the total mental process induced in the experiments of these investigations has been considerably different from what we find it to be in learning the spelling of a word. Though somewhat the same factors are present in learning, their setting is different and their combined functioning is not the same. For this reason seemingly valid deductions from the results as applied in our present problem become unsafe, and, as we shall see later, are quite fallacious. Our problem might therefore be stated as not that of the separate and isolated investigation of individual memory factors, but as the determination of the complex relationship of all factors entering a mental activity as found in life. This does not preclude their experimental isolation and control. The object of the analysis sought includes the determination of what is the best method in orthography. Assuming this analysis to be made, we may ask what variation and control can be introduced into the total process that will induce a better memory, or result in a saving of time in memorizing.

II. Previous Investigations.

We have for a long time had an *a priori* analysis of the factors that *may* enter the learning and recall of the spelling of a word. It is obvious that in the recall the writing of a word may follow (*a*) the auditory imagery of the letters, or (*b*) the visual imagery of the letters, or (*c*) the incipient vocalization of the letters. It is also obvious that the word may be learned through auditory or through visual perception, and that in either case the learning may be aided by accompanying vocalization, and perhaps also by simultaneously writing it. The history of pedagogical opinion shows that each of these factors in learning has in turn been regarded by different writers as the most important for orthography, and reasons for these different claims have been elaborated with considerable detail. Upon the basis of these opinions the different methods of teaching have been developed, putting dif-

ferent degrees of stress upon the auditory, the visual perception, upon vocalization, and writing.[1] But general observations and deductive methods have clearly not been adequate to determine what the facts are among these mere possibilities.

A. *Visual and Auditory Presentation of Verbal Material.* —In the more recent discussions the results of certain memory studies have been drawn upon to help decide the question. The relative value of visual and auditory presentation of verbal material has received attention from a number of investigators. The general result of their studies has been that either the visual or the auditory presentation may be the better, depending, first, upon the age of the person, and, second, upon whether the material is meaningless or meaningful. For meaningless material, nonsense syllables, visual presentation is the better, irrespective of age.[2] For meaningful material, familiar words, auditory presentation is the better with the younger school children, while visual presentation is the better with the older children and with adults.[3] That auditory presentation should be better than visual with the younger school children, while the reverse holds true with the older children and adults is explained by Kirkpatrick, Hawkins and Pohlmann by the fact that the younger children are less familiar with written than with spoken language, while with age this familiarity with the written language increases, and school methods also change from aural to visual. To this Pohlmann adds that auditory presentation induces better attention than does the visual. As regards the fact that for nonsense syllables visual presentation

[1] A very good review of the pedagogical discussions in Germany on this matter is given by Lay: *Furher durch den Rechtschreib-Unterricht.* Wiesbaden, 1899. See also Meumann, Vorlesungen, Vol. II., Chapter XV.

[2] Pohlmann, *Experimentelle Beiträge zur Lehre von Gedächtnis.* Berlin, 1906.

[3] Pohlmann, Calkins ('A Study of Immediate and Delayed Recall of the Concrete and the Verbal,' PSYCH. REV., Vol. V., 1898), Hawkins ('Experiments on Memory Types,' PSYCH. REV., Vol. IV., 1897) and Kirkpatrick ('An Experimental Study of Memory,' PSYCH. REV., Vol. I., 1894) have obtained both these results. MacDougall ('Recognition and Recall,' *Journ. Philos., Psych., and Sci. Meth.*, Vol. I., 1904) found visual presentation the better with adults. Whitehead ('A Study of Visual and Aural Memory Processes,' PSYCH. REV., Vol. III., 1896) found visual presentation the better for nonsense syllables with adults. Bingham ('Memory,' PSYCH. REV., Vol. I., 1894) found the same for numerals with adults.

is better than auditory irrespective of age, Pohlmann notes, first, that the auditory perception of the syllables is difficult; there is often uncertainty as to what the sounds are; second, in auditory presentation, words can be readily translated into visual imagery, while for syllables this is a difficult and slow process.

B. *The Influence of Motor Processes.*—The influence of motor processes accompanying the visual or auditory perception of the material to be memorized has also been made the object of special investigation. Thus in committing to memory groups of pictures of the deaf-mute alphabet Smith[4] found that the errors in recall were sixteen per cent. less for those series in which the observers were allowed to form the letters with the hand, as compared with series in which this motor factor was excluded. Likewise, others have concluded, from experiments that will be considered in more detail below, that writing words simultaneously with seeing them is a considerable aid in learning them. But this class of motor processes must necessarily be relatively remotely related to learning and memory. The motor processes involved in the vocalization of verbal material show a closer connection. Most adult persons readily observe a considerable tendency to vocalize as they read. Such vocalization is equally readily observable with children. Lay[5] has in a rough way made some observations on the amount of such vocalization on school children of different ages. He found that the degree of vocalization with the individual and the number of children in whom it was readily observable decreased considerably with age. Secor[6] in making a more careful study of the minor movements of the larynx in reading, with four trained observers, concluded that the complete elimination of articulation in reading *is possible*, when special efforts are made to do so. He employed the laryngograph to get a graphical record of the movements of the larynx as well as

[4] 'On Muscular Memory,' *Am. Journ. Psych.*, Vol. VII., 1896.

[5] 'Anschauungs- und Gedächtnistypen in Volksschul- und Seminarklassen. Experimentelle Untersuchungen zur Vertiefung des Prinzips der Anschauung.' Leipzig, 1903.

[6] 'Visual Reading. A Study in Mental Imagery,' *Am. Journ. Psych.*, Vol. XI., 1899–1900.

introspection, and found the two methods about equally good for detecting slight vocalization. Curtis,[7] on the other hand, employing a different form of laryngograph, was able to obtain graphical records of articulatory movements, in mentally reciting a poem or prose, of which the observers were for the most part unaware.

From the results from these different sources it is perhaps safe to say that some tendency to vocalize the words in reading, and in memorizing the verbal material used in memory experiments is almost universally present. In agreement with what would be expected from this, Cohn,[8] Fränkl,[9] Lay[10] and Smith[11] found that when this vocalization is arbitrarily limited or excluded in learning verbal material the amount that can be recalled is correspondingly decreased.

C. *Experimental Studies in Orthography.*—Lay,[12] Fuchs and Haggenmüller,[13] and Itschner[14] have attacked the problem of the analysis of the processes in learning the spelling of a word directly with regard to their relative value. They compared the visual and auditory methods of presentation, attempted to determine the influence of excluding vocalization in different degrees, and the influence of writing the word simultaneously with its visual presentation. As the present study is for the most part concerned with this same general problem, we will consider these experiments in more detail. All these investigators made their experiments on classes of school children in the different grades. Lay and Itschner used nonsense words for material. Fuchs and Haggenmüller used unfamiliar

[7] 'Automatic Movements of the Larynx,' *Am. Journ. Psych.*, Vol. XI., 1899–1900.

[8] Experimentelle Untersuchungen über das Zusammenwirken des akustisch-motorischen und des visuellen Gedächtnisses,' *Zeitschr. f. Psychol. u. Phys d. Sin.*, 15 Band, 1897.

[9] *Ueber Vorstellungs-Ellemente und Aufmerksamkeit.* Augsburg, 1905.

[10] *Anschauungs- und Gedächtnistypen.* Leipzig, 1903.

[11] 'On Muscular Memory,' *Am. Journ. Psych.*, Vol. VII., 1896.

[12] *Fürher durch den Rechtschreib-Unterricht.*

[13] 'Studien und Versuche über die Erlernung der Orthographie,' *Schiller's Sammlung von Abhdl. aus dem Gebiete der päd. Psychol.*, II. Bd., 4 H.

[14] 'Lay's Rechtschreibreform,' *Jahrbuch d. Vereins für wissenschaftliche Päd.*, 1900.

German and Latin words. Groups of these were presented to a class in the following different ways:

1. Auditory presentation.
   (*a*) Heard, without vocalization by pupils.
   (*b*) Heard, words pronounced in a whisper.
   (*c*) Heard, words pronounced aloud.
2. Visual presentation.
   (*a*) Seen, without vocalization by pupils.
   (*b*) Seen, words pronounced in a whisper.
   (*c*) Seen, words pronounced aloud.
   (*d*) Seen, letters pronounced aloud.
   (*e*) Seen, copied simultaneously by pupils.

In the auditory presentation the words were read, not spelled out to the pupils. The method of excluding vocalization was that of requesting the pupils to hold the tongue between the teeth while the words were presented. Lay, and Fuchs and Haggenmüller kept the number of repetitions in presenting a group of words the same for a given series, and the presentation time therefore varied, it being necessarily longer for the 2 (*d*) and 2 (*e*) series than for the others. Itschner kept the presentation time constant and varied the number of repetitions accordingly. The directions to the pupils as to vocalizing in 2 (*e*) varied but never called for vocalization of the letters. The following table is derived from their results, the figures being average number of errors in recall per pupil per group of words.

	Lay.	F. and H.	Itschner.	Average.
1a	3.04	1.75	2.93	2.57
1b	2.69	1.90	3.39	2.66
1c	2.25	1.45	2.61	2.10
2a	1.22	.84	1.40	1.15
2b	1.02	.73	1.70	1.15
2c	.95	.76	1.47	.72
2d	1.59	.58	2.10	1.42
2e	.54	.37	1.62	.84

These figures are not in themselves entirely conclusive with reference to all the points that the experiments aimed to decide, since there is considerable disagreement for some of the series. Lay, on the basis of his own results, attributes a great impor-

tance to vocalization. In this he is perhaps correct, although Itschner, and Fuchs and Haggenmüller have failed to verify his figures. Itschner concedes that Lay's results are the more reliable because the latter's experiments were more extensive than his own. Many other factors enter to influence the objective results. As these authors have pointed out, on the one hand, vocalization is probably not entirely excluded when the attempt is made to do so, while, on the other hand, whispering and pronunciation aloud is probably a considerable distraction when the experiment is made on a whole class at a time. To this should be added that holding the tongue between the teeth to exclude vocalization also probably causes some distraction to the unpracticed pupil. In the comparison of the relative value of visual and auditory presentation there is an obvious criticism to be made against the conduct of the experiments. It is clear that so far as the words were at all unphonetic the auditory presentation would have to result in the larger number of errors, since the words only and not the letters were read to the pupils. The experiments do not give any results at all on the point in question. A second criticism concerns the failure to keep the presentation time constant for the different series between which comparisons were made. Lay argues that the longer time it took to present the 2 (*e*) series was not the cause of the small number of errors. He made a few special tests on this point. But the results on which he bases this conclusion are not decisive. His tests were made under too varying conditions, and the exceptions to his conclusion too numerous in his results. Itschner's results, for which the presentation time instead of the number of repetitions of a group was kept constant, probably come much nearer showing the correct relation of factors here. It is seen that he got rather more than less errors when the children wrote the words during visual presentation. These three investigators give each a different explanation for the results Lay, and Fuchs and Haggenmüller obtained in series 2 (*e*). Lay attributes the small number of errors for this series to an influence of the writing *per se*. Fuchs and Haggenmüller note that in this series the words are seen twice, once as they are presented, and a second

time as they are being written. Itschner explains the results still differently. First, the presentation time, being longer, should reduce the errors. Secondly, when the word is merely seen it readily gives the satisfaction that it is learned, when it is not. But copying the seen word is done from immediate memory. This determines whether the word is learned or not, and gives the opportunity to look a second time at the part that is not learned. We shall be able to demonstrate the validity of this last contention with results of special tests on this matter.

III. Method and Procedure.

Our method and general procedure differed from that of Lay and others in two essential ways. First, only a few and trained observers, four in all, took part in the different series of the experiments. The aim, as was stated above, was first of all a detailed thorough analysis for all the factors entering the total mental process of learning and recalling. Secondly, much stress was put on introspective observation as the chief method of making this analysis. With reference to the number of observers, employed, we recognize the validity of the criticism that in the complexity of any mental function there *may* exist a considerable range and variety of individual differences, which the procedure with few observers may fail to determine. The reply is that any procedure with a larger number of observers which fails to make the detailed analysis for each observer fails likewise in the determination of individual differences of the sort in question, and thus arrives no more at generalizations that might hold true of the average person than does our procedure. Those who have worked on this problem have attempted two different things. First, they have aimed to find the method and conditions of presentation that would give the least errors in recall for the average person. Second, with the average number of errors obtained under the different conditions, they have attempted to analyze the presence and relation of mental processes that produced their figures. The study of the first of these questions obviously requires a large number of observers. For the study of the

second question the method of Lay and others is in our opinion quite inadequate, when employed alone. Our procedure is the reverse. It attempts to make the analysis in question mainly through the introspective observations, and employs the figures mainly as an aid to determine the relative influence of the factors found, believing this to be the only safe procedure. The danger of inferring the existence and manner of fuctioning of a mental process from objective results in so complex a function as memory has been often enough demonstrated. In this case we have the inference of what is a possibility; in introspection we have the observation of what is a fact. We feel assured that if Lay and his associates had employed direct observation with trained observers they would have explained their large number of errors in their auditory presentation of words, and the small number of errors when in addition to seeing the words the pupils also wrote them out, differently, and they would also have been able to point out the significance of the large number of errors when the pupils were required to vocalize the individual letters during presentation of the word.

With the four observers mentioned, five different series of experiments were undertaken, two observers taking part in each series, not counting preliminaries. The series were taken successively, their nature being determined by what seemed important from the progress of the study. In all cases unfamiliar and difficult words were used, uniformity being obtained, first, by trying to make them so in choosing the individual words, and, second, by collecting a large number and then making up the different ten word groups used for a series by selecting by chance. The different series were as follows: (1) Comparison of visual and auditory presentation. (*a*) Successive visual presentation of the individual letters of a word at the rate of two letters per second and two seconds intervening before the beginning of the next word of a group of ten. The successive exposure of the letters was made with a kymograph. (*b*) Successive auditory presentation of the individual letters of a word at the same rate as in the visual presentation, and with all other conditions the same. In this the words were spelled out to the observer, the experimenter following a metronome, in-

audible to the observer. The observers, who will be designated by the letters *A* to *D*, were *A* and *B*. Ten groups of words of ten words each for each observer for the visual and for the auditory presentation were used. (2) The influence of vocalization by the observer of the letters or of the syllables. In this the letters of a word were presented simultaneously, visually. The words of a group were presented successively. A word was exposed for seven seconds, with one second intervening before the next word of a group was given. (*a*) The observer tried to rule out all vocalization, the tongue being held between the teeth. (*b*) The observer avoided vocalization of the individual letters of a word, but pronounced the syllables silently. (*c*) The observer vocalized the individual letters but not the syllables. *C* and *D* observed in this series. Six groups of ten words for each observer for each of (*a*), (*b*) and (*c*) were used. (3) The influence in visual presentation of syllabification and the use of diacritical marks of pronunciation. In this a group of words was presented simultaneously for a total time equal to the total time spent in the presentation of a group in '2' and in all the following series. (*a*) There was no division into syllables and no diacritical marks of pronunciation. (*b*) The word was divided into syllables and the diacritical marks were added. *C* and *D* observed. Ten groups of words for each observer for each of (*a*) and (*b*) were used. (4) Successive exposure of the words of a group compared with simultaneous exposure. For this comparison no separate series was taken. The results for '3.(*a*),' and '5.(*c*)' give this comparison. (5) The influence in visual presentation of a few seconds interval allowed for the immediate recall of an exposed word before exposure of the next word of a group. In this the total time spent on a word remained constant at eight seconds, but the relation between the time given for exposure and the time given for immediate recall varied as follows: (*a*) Three seconds exposure and five seconds for immediate recall. (*b*) Five seconds exposure and three seconds for immediate recall. (*c*) Seven seconds exposure and one second for immediate recall. *C* and *D* observed. Ten groups of words for each observer for each of (*a*), (*b*) and (*c*) were used.

In all cases the words were given in groups of tens. In all cases, except the simultaneous presentation of the ten words of a group, a group was presented three times, giving 240 seconds as the total time for learning ten words. For presenting the words successively and regulating the relation of the exposure time for a word and the time allowed for immediate recall a special apparatus was used. One part consisted essentially of a large camera on the ground glass of which the observer saw the image of the typewritten word, this giving a means of regulating the size of the letters and the distance from the eyes independently. A second part consisted of a fall apparatus, the drop-board of which carried the sheet of typewritten words in columns of ten. A third part included a metronome with electrical connections driving a special contact apparatus which made and broke a circuit at the relation of intervals stated. In the circuit of the latter was placed an electro-magnet whose attached lever dropped and held the drop-board of the fall apparatus in the corresponding intervals. Immediately after a group was learned the experimenter pronounced the words to the observer for recall, repeating if necessary. The observer then took as much time as he wanted to spell the word, the experimenter and not the observer writing down the spelling given. In the first two series only an immediate recall was taken. In the third series the recall was repeated four days after the immediate. In the fifth four recalls were taken, the second being four days after the immediate and the third and fourth eight and sixteen days, respectively, after the last recall. The results show, however, that the number of errors in recall did not increase after the second recall because the words were by this time entirely forgotten. For these last two recalls in the fifth series the results will, therefore, not be considered. For all the series it was attempted to get a thorough introspective analysis of the manner of learning the words, and of the process of recall.

IV. Analysis of Results.

A. *The Recall and Recognition Processes.*

In pronouncing the word to the observer for spelling, it was found that the processes that entered into the recognition of the word and the recall of its spelling, with one exception, did not vary in any noticeable degree with the manner of learning the word or with the method of presentation. The recall and recognition processes were the same in all the series taken, including auditory presentation. This was not the case with the factors entering the learning of a group of words. We may, therefore, consider recall and recognition first, leaving the analysis of the factors in learning for a separate treatment for each special series.

1. *Recognition of the Word as a Whole.*—It will be important to bear in mind from the outset that we never have in this experiment the ordinary case of recognition; a stimulus as given in perception is never repeated for recognition. In auditory presentation the observer heard only letters. In visual presentation he saw only letters. In both cases he was given the *sound* of the *word* when it was pronounced to him for spelling. If, therefore, he recognized the word when pronounced to him it could not be recognition of what he had in perception. The recognition must in this case be through the imagery or motor processes that were associated with the perception in learning and which was aroused again by the sound of the word. It thus happens that the manner of recognizing gives a secondary means of determining the prominence and function of the processes in learning.

The observations require a distinction to be made between the recognition of a word as a whole and the recognition of the correctness of its spelling as recalled by the observer. Quite often the two were entirely separate processes. Of the recognition of the word as a whole three forms were observed. (*a*) The word was at once recognized on pronunciation to the observer. No secondary processes were present to mediate recognition; it was direct through the sound. This was the usual form of recognition, by far the majority of cases belonging to

this class. (*b*) The word was recognized through its visual image that the unrecognized sound aroused. (*c*) No definite recognition of the word entered, but its spelling as finally decided upon was in some degree accepted, mostly through other than memory factors. In a rough way these three forms of recognition were correlated with different degrees of familiarity of the words, the most familiar or best learned words belonging to the first class. The incipient or actual pronunciation of the word by the observer was sometimes regarded by *D* as adding something to the recognitive familiarity in the case of an easy word. But for *D* the vocalization and the auditory image of the sound as he would himself pronounce the word constituted an all but inseparable complex. It is, therefore, possible that even in this case the vocalization was an aid only indirectly, through the auditory image associated with it. For *C* this auditory image seems to have been less prominent, and vocalization was never mentioned as an aid to recognition. In learning, *C* pronounced the syllables, as did *D*.

On the whole, it seems valid to infer from this that when the word is recognized through its sound, which has never been heard at all before, the auditory image must have been an important, although not necessarily a consciously prominent factor in learning. The vocal process becomes important then to the degree in which it is required for the arousal of this auditory image.

2. *The Processes in Recall.*—The recall of the spelling of a word and the determination of which were the correct letters was usually a very mixed process, and one in which the syllable much more than the letter stood out as the unit. We may distinguish four forms of recall, but it must then be borne in mind that in any given word the different syllables might belong to two or all four forms. (*a*) The word was spelled through immediately on hearing it, with little or no definite visual imagery of the letters. The observer recognized the correctness of the spelling from his vocal-auditory process. (*b*) More or less definite visual imagery of the letters entered, either at once on hearing the word or accompanied the vocalization in spelling. But the attention was not directed to this

visual imagery, which came up of itself and did not seem to be necessary for spelling or recognition. (*c*) The vocal-auditory process was insufficient for recall or recognition and was not noticeably an aid. The recall was through definite visual imagery of the letters, which either came up immediately and correctly, or different letters were voluntarily visualized and those chosen which looked correct. (*d*) The sound of the word was definitely and consciously taken as a guide in constructing a spelling, with definite visual imagery of the letters as in the last case, which was then made more or less phonetic. There was little or no recognition, in the technical sense, of the correctness of the letters chosen, which were accepted more or less as correct on the basis of non-memory factors.

These four forms of recall were rather closely correlated with the different degrees in which the words had been learned and their familiarity, the easiest belonging to the first, the most difficult to the last. They correspond very well to the general rule that in any given complex mental process whose end factor is a motor process, the subsidiary imagery which is at first an aid in learning is gradually eliminated until only the beginning and the end factors remain, in this case the sound of the word as pronounced to the observer and his vocalization of the letters in spelling. In agreement with this and the degree of memory induced in this expirement, but very few cases belonged to the first form of recall even for the recall immediately after the group had been presented. A few more belonged to the second class, but over three fourths in immediate recall belonged to the third. The last was particularly prominent in the delayed recalls and for the specially difficult words. This range of variety of modes of recall was found by observer *D*. *C* never reported the first form, with whom the visual imagery was in general more prominent and vocalization less so. For the typical total memory process we have left, therefore, one in which the word is recognized directly through the sound as pronounced to the observer, and the recall of its spelling takes place in terms of visual imagery of the letters. In this the complete absence of all auditory imagery of sounds as given in auditory presentation deserves special

attention. No auditory imagery of heard letters ever played a part in recall. On the other hand, another class of auditory imagery seems to have been more important for recall than its prominence in consciousness as determined by the introspections would lead one to infer. This is the auditory image of the syllable or word as the observer hears himself incipiently pronounce it. This is, therefore, imagery that is necessarily very closely associated with the vocal process, and is entirely independent of the method of presentation. It may come in quite as readily with the observer's pronunciation of the seen letters as with his pronunciation of the heard letters. Such imagery was only occasionally present in recall, coming to the foreground when the experimenter's prounuciation of the word was considerably different from what the observer had used in learning. In such cases the observer's statement was frequently to the effect that the word as he heard it pronounced suggested his own pronunciation, which in turn at once gave the visual imagery of the letters. We have to deal here with a factor, the closely associated vocal-auditory process, which apparently may play a great rôle in learning but which for the most part does not enter as a means of recall. But since in recall it is the sound of the word that is to suggest the visual imagery of the letters, it should follow that whatever helps to fix the association between this sound and the imagery of the letters will be an especially effective aid for memory even though the word is quite unphonetic in its spelling.

B. *Comparison of Visual and Auditory Presentation.*

1. *Factors in the Learning Process as Affected by the Method of Presentation.*—It will be remembered that in this first series, comparing the visual and auditory methods of presentation, all the other objective conditions for the two methods were identical, the observer seeing the letters of a word successessively at the rate of two a second in the one case, and hearing them at this rate in the other case. Only the results of observers *A* and *B* figure in the table below. But in the preliminaries for the series, taken by *C* and *D*, the latter made out the introspective analysis of the factors in the learning as well as

did *A* and *B* in the regular series. What is given in this analysis holds true of all observers. In fact, no individual differences of importance for the present comparison were determined.

In the visual presentation the main effort of the observer was directed to getting the letters combined into syllables. Unless he succeeded in this the whole word was instantly forgotten, before the next word appeared, about as completely as would have been the case if nonsense syllables had been substituted for the letters and presented at this rate. This combining was done by visualizing the several letters of a syllable simultaneously, which necessitated holding in mind in terms of visual imagery the letters that were just passed until a recognized syllable was completed in presentation, at which point the whole syllable usually flashed out definitely and clearly. With this clear visual imagery of the syllable the latter was usually pronounced, this vocalizing being more prominent for *B* and *D* than for *A* and *C*. *D* noted that there was a considerable tendency to pronounce the individual letters as they were seen, but that such pronunciation interfered with combining the letters visually into syllables, there not being time for both processes. *A* and *C* never vocalized the letters.

In the auditory presentation the process of learning was not essentialy different in the nature and function of the factors that entered. The main effort was again directed to getting the letters combined into syllables, and for the same reason. The method of combining them was again that of visualizing them simultaneously. The individual letters were at once visualized on hearing them, and the observer worked no more with auditory imagery in auditory presentation than he did in visual presentation. The tendency to pronounce the visualized syllable was on the whole somewhat less than for visual presentation. But this seems to have been the result of the slowness of the visualizing process and the short time the conditions of the experiment allowed for it; the visualizing took most of the attention and time of the observer.

2. *The Errors in Recall.*—It has already been stated that the manner of learning a group of words and the method of

its presentation did not noticeably affect the process in recall. It must be added here, however, that the successive presentation of the letters in both cases of this series was a poor method, in that it hindered syllabification, which is seen already to be an important process. From this it resulted that about half of the words were not recognized at all by the observers when pronounced to them immediately after a group had been presented. We may turn at once to the objective results for this series. Table I. gives the average number of errors made in immediate recall per group of ten words for observers *A* and *B*.

TABLE I.

	(*a*) Visual.	(*b*) Auditory.
A	19.3	24.3
B	12.0	16.0
Average	15.7	19.7

This difference in the number of errors in recall in favor of the visual presentation is undoubtedly not as large as it should be to give a correct idea of the relative value of the two methods, inasmuch as only a low degree of memory was induced in either case. The observers' statement that only about half the words were recognized at all when pronounced to them is reinforced by the further fact that the number of errors is, roughly speaking, about four times as great as for the immediate recall of later series. It is evident, therefore, that the difference between the two methods is at least to some extent reduced because the results are in part reduced to a common level by the words being so poorly learned in either case. The total presentation time for a word was approximately the same in this series as in the others. We have, therefore, two things to account for. First, the large number of errors in this series for both methods of presentation. Second, the difference in the number of errors for the visual and auditory presentation. The answers to both are clearly given in the introspective observations. The letters of a word must be presented simultaneously to facilitate syllabification, if the word is to be learned readily, for syllabification is essential. Secondly, when they are presented successively the auditory presentation is the poorer because the observer finds it impos-

sible to work with auditory imagery of the heard letters as he does with visual imagery of the seen letters. Substituting visual imagery for the heard letters takes a good portion of the time and also of the attention from other essential processes, the combining into syllables and pronunciation. In addition to this, since the recall is in terms of visual imagery in both cases, we have the recall of what was given in actual perception for visual presentation, and the recall of what was present only in the form of imagery for auditory presentation. Since in auditory presentation the letters must necessarily be given successively, there are these several reasons why it should be a poorer method than the simultaneous visual presentation of the letters.

C. *The Influence of the Observers' Vocalization of the Letters or of the Syllables.*

In this second series the observer learned the group of words in successive visual presentation in the one case without any pronunciation of the letters or syllables, so far as possible, in the second case he pronounced the syllables and not the letters, and in the third case he pronounced the letters and not the syllables. As is seen, this series was intended to determine the influence of vocalization, and to discriminate between the influence of vocalization of letters and of syllables. The results of the first series suggests that these two kinds of vocalization may differ considerably in their effect on learning.

1. *The Observers' Direct Observations.*—In this and in the following series we have to take individual differences into account. In learning a group of words *C* had no difficulty in excluding the vocalization entirely, or in vocalizing syllables only or letters only. *D* found it quite impossible to entirely exclude the vocalization. The manner of learning for *C* and *D*, therefore, varied considerably. Observer *D* noted that when, or in so far as, he succeeded in eliminating all vocalization in learning, the words would not even be recognized as words as he looked at them, and that the attempt to keep out the vocalization was a great distraction. What usually occurred in

place of this was a very incipient and incomplete vocalization of the syllables. A special feature of this procedure was the coming into prominence of the auditory imagery of the syllables; *D* heard himself pronounce the words in imagination, and this auditory image would ring out the clearer the more the vocal part of the vocal-auditory process was voluntarily subdued.[15] Breaking up the word into syllables through a purely visual process was impossible for him; syllables had no meaning or existence even, except as accompanied by a vocal-auditory process. The vocalization of the letters only tended also to prevent the syllabification and non-recognition of the word. In this, syllabification took place in part by the auditory image of the syllable flashing in with the pronunciation of its last letters. For several groups of words taken last in this series, syllabification was aided by pronouncing the letters of the syllables in rhythms, with long pauses between syllables. *D's* natural manner of learning a word included the pronunciation of the syllable only in case of easy syllables, and the pronunciation of the individual letters in addition in the case of difficult syllables. On the whole, he regarded vocalization of the syllables only as the best method, but vocalization of the letters of hard syllables as necessary, while the attempt to exclude, so far as possible, all vocalization was both extremely difficult and seemed poor method.

Since *C* had no difficulty in excluding the vocal process, the manner of learning was for this observer quite in accordance with what was demanded by the experiment in this series. One further point of difference, however, which was a direct result of excluding the vocal process, is to be noted for *C*. Since throughout this series a word was presented for seven seconds with only one second interval following before the presentation of the next word, there was considerable opportunity for trial recall during the presentation time. This is a natural procedure and it requires a special effort to exclude it when conditions for its possibility are given. We shall give this a special

[15] This seems to be in harmony with a result obtained by Secor, who found that in the attempt to exclude articulation in reading the auditory element was much more persistent than the vocal. *Am. Journ. Psych.*, Vol. XI., 1899–1900.

consideration later. In the present case, trial recall during the presentation of a word entered to some extent when all vocalization was excluded, but never when the letters were pronounced while learning. Since pronunciation of the individual letters was for *C* the unnatural method of learning which required special effort to follow, and since it is at the same time a much slower process than merely noting the letters visually, we have this double reason why trial recall should enter in the one case and not in the other. Pronunciation of the syllables only seemed to *C* the easiest and most natural of the three ways of learning, and pronunciation of the letters by far the poorest and most unnatural way.

As regards the readiness of recall and recognition of a word when pronounced to the observer, *C* noted some differences for the different ways of learning that are of special significance. When the syllables were vocalized in learning the word was at once and readily recognized when heard. When the letters only were vocalized, or when there was no vocalization in learning, recognition of the word was much less certain. Further, the heard word did not suggest the visual imagery of the letters readily, and, in the case when letters only had been vocalized in learning, the visualized letters looked indifferent as to correctness. This reflects in some degree the manner of functioning of the vocalization of syllables.

2. *The Errors in Recall.*—Table II. gives the average number of errors per group of ten words, as before, for the three ways of learning.

TABLE II.

	C.	*D.*
(*a*) No pronunciation	5.7	13.7
(*b*) Syllables only pronounced	4.3	8.0
(*c*) Letters only pronounced	14.7	7.7

It appears from these figures that only the second method of learning had the same influence for the two observers, while for the first and third methods the results for the two observers are in complete disagreement. These individual differences, however, are the differences that were to be expected from the

analysis of the learning process already given, and are in accord with the results of the following series. The ease with which *C* excluded the vocal process in learning, and the difficulty *D* had in attempting to do so may be taken in part as a measure of its relative prominence and value for the two observers, but perhaps only in part. Thus we find that the attempt to exclude it entirely increased the number of errors in recall some for *C*, but nearly doubled it for *D*. As regards the effect of the vocalization of syllables and the vocalization of letters, we must recall here that according to the direct observations of *D* one seemed the better method for easy syllables, the other the better for difficult syllables, and either a much better method than the first. The relative number of errors in recall for *D* verify his introspective analysis. The large number of errors for *C* when letters only were vocalized in learning indicates that this vocalization has been a positive hindrance either to the purely visual method of learning or to the combining of letters into syllables through the pronunciation of the latter, or to both. Since pronunciation of the syllables only is the best of the three methods for *C*, it is to be inferred that it is due in part to the latter. Results of the next series, however, will show that interference with a purely visual process of learning was for *C* especially prejudicial to the best results.

D. *The Influence of Syllabification and the Use of Diacritical Marks of Pronunciation.*

With the fact established that the mode of recall is, as a rule, through visual imagery of the letters, the problem for the learner becomes that of getting as close an association as possible between the sound of the word as it will be given to him for spelling and the visual imagery, because it is this sound that is to suggest the letters either directly or through his vocalization with which he may repeat the heard word. Since in learning the observer does not hear the word, but only the letters, or sees only the letters, he must supply this vocal-auditory process himself. In the preceding series we have attempted to regulate the vocal process during the learning; over the

auditory imagery that may be associated with this we have but little direct control. But requiring the observer to pronounce the syllables in learning insures his getting this association between the sound of the word and the visual imagery of the letters only so far as he pronounces the word correctly. The present series aimed to determine what the effect would be if aids to this correct pronunciation were introduced. This might be done by pronouncing the words to the observer simultaneously with their visual presentation, or the written word as presented might be divided into syllables and the diacritical marks of pronunciation added. After a few preliminary trials the latter was chosen as probably the better method.[16] In this third series the ten words of a group were presented simultaneously, in the one case the pronunciation being indicated as stated, in the other no such indication being given.

1. *The Observers' Direct Observation on the Learning.*— It was found at once in the introspections that the spacing of the syllables and the presence of the diacritical marks would have two different effects, opposed to each other in their manner of affecting the number of errors made in recall. Observer *C* noted that the spacing and the marks introduced a confusion in the visual process of learning. So much was this the case that in the trial recalls during the learning the words were purposely visualized without the spaces and the marks. This resulted in it taking about three times as long to go over the group of words for the first time. *D* noted the same confusion entering to some extent, but for him this seems to have disappeared later. On the other hand *D* found that he could go over the group of words in less time when the spacing and marks were added because of the reduction of the time required for breaking up a word into syllables and determining the pronunciation.

2. *The Errors in Recall.*—The next table, giving the number of errors in the same way as before, brings out the fact

[16] As will be seen below, the results of this series did not prove the correctness of this first impression. It is quite likely that for some observers the former method would be the better. Time did not permit taking a special series to determine this point.

that both of these influences of the spacing and marks have been considerable, one for one observer, the other for the other.

TABLE III.

	(a) Pronunciation not Indicated.		(b) Pronunciation Indicated.	
	Immediate Recall,	4d. Recall.	Immediate Recall,	4d. Recall.
C	2.9	18.0[17]	5.8	20.0[18]
D	4.1	21.9	2.3	14.5
Average	3.5	20.0	4.1	17.3

Roughly speaking, the indication of the pronunciation has doubled the number of errors for *C*, and reduced them a half for *D*. This individual difference is in accordance with that found in the second series, both showing that non-interference with the visual process in learning is of the first importance for *C*, while non-interference with the correct vocalization of syllables is of equal importance for *D*. We are not to conclude from this, of course, that the indication of the pronunciation was in itself not an aid for *C*. For in the second series we have already seen that pronunciation of the syllables gives the least errors, and an aid to correct pronunciation, if other conditions remained the same, should reduce the errors further. On the other hand, we found that separating the syllables and adding the marks was for *D* also some hindrance in learning.

E. *Comparison of Successive and Simultaneous Exposure.*

For the successive exposure that will be considered in the present comparison a word was exposed for seven seconds with an interval of one second following before exposure of the next word. The results of this will be compared with those of the preceding series for which no pronunciation was indicated. We are concerned now with factors that do not belong exclusively to learning and remembering the spelling of words. But their study was undertaken because they seemed of special significance for the present problem.

1. *The Observers' Direct Observations on the Learning.* (*a*) *Successive Exposure.*—Some matters to be taken into account at this point have already been stated in connection with

[17] Average for seven groups of words only.

[18] Average for nine groups only.

the previous series. We may recall that the usual procedure included an attempt to break up the word into syllables and to fix on the pronunciation of the word, and that for observer *D* the letters also of the difficult syllables were vocalized. The procedure demanded that all of the seven seconds should be used in looking at the word and that all trial recall should be excluded. But seven seconds was often longer than necessary to go over the word several times, and the tendency to try to visualize especially the difficult syllables to determine whether the word was learned was constantly present. Trial recall, therefore, entered to some extent, and is at once some index of its importance.

(*b*) *Simultaneous Exposure.*—For the individual word the procedure in learning was quite the same as in the successive exposure, except in the amount of trial recall that entered. In this case the observers were allowed to do as they chose, and trial recall for a word until it could be spelled in immediate memory was the rule. The simultaneous exposure resulted also in a distribution of the time for the ten words of a group according to the ease with which they could be learned. A third difference consisted in a lack of uniformity of attention and effort in the present case. Successive exposure with always a definite and limited time allowed for each word was a considerable aid in keeping the attention constantly near its maximum. Simultaneous exposure with the opportunity to return to a word at any time and no definite knowledge of how much of the total time allowed was left favored a lowering of effort.

2. *The Errors in Recall.*—

TABLE IV.

	(*a*) Successive Exposure.		(*b*) Simultaneous Exposure.	
	Im. Recall.	4d. Recall.	Im. Recall.	4d. Recall.
C	5.4	16.8	2.9	18.0
D	6.1	11.4	4.1	21.9
Average	5.8	14.1	3.5	20.0

The comparison of these figures brings out two things. First, for the recall immediately after a group had been learned the number of errors is much smaller for simultaneous exposure than for the successive. Second, for the second recall four

days after learning the reverse holds true. Considering the differences in the manner of learning in the two cases, we may offer the following interpretation. In the simultaneous exposure each word is learned only to the degree required for successful recall the moment after it is seen. When all the words have been learned in this manner the effort lags because of the feeling of assurance that all can be recalled. The use of trial recall makes this possible, and is also the means of distributing the time correctly for the ten words. This results in few errors in immediate recall even for the difficult words, because more time has been put on these. It results also in many errors in the delayed recall because of the many words that have been only barely learned and on which more effort might have been spent. In the successive exposure the constant maximum effort and the equal amount of time spent on all the words result in many words being thoroughly learned, reducing the errors for these in the delayed recall. The relative absence of trial recall and the impossibility of giving more time to the difficult words than to the easy ones result, on the other hand, in many words not being learned at all and increases the number of errors for the immediate recall.

F. *The Influence of a Few Seconds for Immediate Recall Following the Exposure of Each Word.*

As was stated above, in the fifth series the time allowed for each word for one presentation of a group remained constant at eight seconds. But in one case each word of a group was exposed for three seconds with five seconds following for immediate recall, in a second case the exposure time was five seconds with three seconds following, and in a third it was seven seconds with one second following. These relations of exposure time and interval following for immediate recall were chosen after some preliminary observations as probably including the optimum. The observers were instructed to use the exposure time exclusively for the perception of the word, and the interval following exclusively for immediate recall. We have seen the influence of trial recall, which gives the observer an opportunity to find the difficult points and to know

when he has overcome them. This includes the immediate recall with which we are now concerned. The object of this series was to determine whether it was not better to spend a part of the time on such recall than to put it all on perception, even though the observer could not return to the word when he found that he could not yet recall it, nor put more time on the difficult words and less on the easy ones.

1. *Direct Observations.*—The three seconds exposure was often found to be too short to complete the processes for a difficult word, namely, breaking it up into syllables, pronouncing it, and giving special attention to the difficult syllables. This was especially the case with observer *D*, who included vocalization of the individual letters of difficult syllables. The seven seconds exposure was usually more than necessary, and trial recall tended to crowd into the exposure time. The immediate recall in the interval following the exposure demanded, on the whole, more time than the perceptive processes, yet about the same was found with reference to the five, three and one second, respectively, allowed for this in the three cases. The five seconds were sometimes more than necessary, and the one second was never enough to do more than to pronounce the word and get a rough incomplete visual image of it. A difference in the uniformity of attention for these different relations of exposure time and time for immediate recall was observed. The attention was naturally kept up best when the time allowed for perception and for immediate recall was in each case just sufficient and not more than necessary to complete the processes entering into each. More time than was necessary to complete them was often wasted.

2. *The Errors in Recall.*—The 3–5, 5–3 and 7–1 in the following table designate the relation of exposure time for a word and interval following in the three cases.

TABLE V.

	a. 3–5.		*b.* 5–3.		*c.* 7–1.	
	Im. R.	4d. R.	Im. R.	4d. R.	Im. R.	4d. R.
C	3.4	15.6	4.7	20.3	5.4	16.8
D	4.8	9.3	5.0	8.0	6.1	11.4
Average	4.1	12.5	4.9	14.2	5.8	14.1

Of these figures those for the recall immediately after a group had been learned interest us chiefly. For the delayed recall they show no conclusive differences as regards the effect of the relation of exposure time and interval following. This is probably due to the fact that the differences are in the first place not so great for the immediate recall as in the comparisons of the tables above and are reduced still more as the words are more entirely forgotten. For the recall immediately after a group had been learned we see that the number of errors is least for the 3–5, and greatest for the 7–1 relation. We may conclude, therefore, that it has been of special value for the memory of a word to convert the perceptive process into terms of imagery instantly after the word was seen; of more value than if the time for it had been spent on repeating the perceptive process. That this should be true still when more than half the time is given to this imagery indicates how very essential it must be.

V. Summary and Conclusions.

One of the things determined will be seen to be of more importance than its separate consideration above indicated. This is the fact that, irrespective of the method of presentation and the manner of learning, the *typical* mode of recall for all observers was through the visual imagery of the letters. This being the case, the problem for the observer becomes, psychologically stated, that of getting as close an association as possible between the sound of the syllables and the visual imagery of the letters.[19] The sound of the word as given the observer for the recall of its spelling must suggest the visual imagery of the letters, whose individual sounds may not be at all indicated in the pronounced word. Secondly, since the individual letters must be presented in learning, there are two things in the first term of this association between the sound of the syllables and the visual imagery of the letters that may be aided in learning: we may facilitate getting the sound accurately, and

[19] We are dealing, of course, only with words in so far as they are unphonetic, since words that are spelled strictly phonetically present no problem for memory at all.

we may facilitate the auditory or visual perception of the letters.

The visual mode of recall also enters as one factor in determining the relative value of the visual and auditory method of presentation. It seems to have been tacitly assumed by some writers that the recall might be in terms of auditory imagery whose arousal might be the easier when the perception has been auditory instead of visual. Our results show, first, that visual imagery is invariably substituted at once for the heard letters, and, second, that the heard letters are never recalled in terms of auditory imagery. This fact alone makes the auditory method of presentation poorer than the successive visual presentation of the letters. The other results, however, on this comparison of the two methods of presentation are of more importance. We have found that the observer's combining the letters at once into syllables as they are presented is of prime significance, and that the successive presentation of the individual letters prevents this. The necessity of giving the letters successively in auditory presentation, therefore, rules out this method as a competitor with the simultaneous visual presentation of the letters.

We see from this that learning the spelling of a word is a quite different process from memorizing a group of words or nonsense syllables, and that the fact that under certain conditoins auditory presentation for the latter is better than the visual does not permit of any conclusion to be drawn with reference to the relative value of these two methods of presentation in learning the spelling of a word.

Lay and his associates have concluded that vocalization is a considerable aid in learning, although Itschner's figures alone do not bear out this statement. We have found that its value depends, first, upon whether it is vocalization of the syllables or of the individual letters, and secondly, upon the relative predominance of the visual processes of the individual observer, and, thirdly, that an auditory imagery connected with the observer's incipient or actual vocalization of the syllable plays a part, and that it is this vocal-auditory process in learning with which the visual imagery of the letters becomes associated. Thus the observer's vocalization of the syllables is always an

aid, but the vocalization of the individual letters may be a hindrance. Other points in the analysis show how the latter may take place. The vocalization of the letters is, in the first place, a slow process and prevents going over a word as often as when it is omitted. In the second place, it may be a hindrance to combining the letters into syllables, especially for the observer who is very predominantly visual. We may offer this as an explanation of Lay's results also, who found that when the children were required to vocalize the letters more errors were made in recall than when such vocalization was not required. It is to be noted further that we have here a process that is an aid in learning, but is not as a rule present as an aid in recall. The vocalization of the syllables probably aids the learning in two different ways. First, in connection with the auditory imagery it may arouse, it determines a correct or fixed pronunciation. Secondly, it is probably a guide to the visual perception, causing especially the grouping of the letters into syllables. It is thus a process that facilitates both factors for the first term of the association mentioned.

We have attempted to determine the influence of a special aid to the vocal-auditory process in learning, by indicating the pronunciation of the word. The results of this series show better than those of the others that the best method of presentation and of learning is a matter of getting the right combination for the individual person, of the several processes that may enter. For the observer for whom the vocal-auditory process was more prominent this aid to the vocal-auditory process reduced the errors in recall about a half. For the other observer, whose method of learning was seen throughout to be more purely visual, the effect of this aid was so slight, and that of the hindrance to the visual process introduced with the spacing of the syllables and the diacritical marks, so great that the latter outweighed the former to the extent of doubling the number of errors in recall. This brings to our attention the importance of presenting the word in such a way as to facilitate its visual perception as much as possible. Several other instances have been mentioned in this study in which a factor that retarded the rate at which the word could be gone

over in perception was found to be a great hindrance. In this connection we must mention the results of studies on the psychology of reading, which show that the rate of reading varies with even a small difference in the size of the letters and style of type.[20]

Finally, turning to other questions than those concerned with the processes present in learning and recalling, their combined functioning and relative value, we found two other matters of importance. First, the use of trial recall in learning, giving the observer the opportunity to distribute his time for the different words accordingly as they are easy or difficult, and to determine when a word is learned. The simultaneous exposure of all the words of a group, making trial recall possible, reduced the errors in recall immediately after a group had been presented from 5.8 in successive exposure to 3.5. But this favorable effect for the simultaneous exposure is lost in the delayed recall, for which the errors increased from 14.1 in successive exposure to 20.0, this being probably due to the complex relationship of factors described above. Secondly, the results of the last series show that a good part of the favorable effect of the trial recall in the simultaneous exposure is due merely to converting the perceptive process immediately into imagery, since such recall the moment after a word has been seen is more effective for memory than when the time for it is all spent on perception. The optimum condition with reference to these last two factors seems to be that relation of exposure time and interval for immediate recall that will permit the observer to just complete the processes that for him enter into each.

[20] Huey, 'Physiology and Psychology of Reading,' *Am. Journ. Psych.*, Vol. XI. Also, *The Pedagogy and Psychology of Reading*, New York, 1908, by the same author. Dearborn, 'The Psychology of Reading,' *Archives of Philos., Psych. and Sci. Meth.*, 1906.

VI. Bibliography.

Bingham, J. Memory. Psychol. Rev., I., 34–39, 453–462 (1894).

Calkins, M. W. A Study of Immediate and Delayed Recall of the Concrete and of the Verbal. Psychol. Rev., V., 451–462 (1898).

Cohn, J. Experimentelle Untersuchungen über das Zusammenwirken des akustisch-motorischen und des visuellen Gadächtnisses. *Zeitschr. f. Psychol. u. Phys. d. Sin.,* XV. Bd., 161–184 (1897).

Curtis, H. S. Automatic Movements of the Larynx. *Am. Journ. Psych.,* XI., 237–240 (1899–1900).

Dearborn, W. F. The Psychology of Reading. An Experimental Study of the Reading Pauses and Movements of the Eye. *Archives of Philos., Psych., and Sci. Meth.,* No. 4, 1906.

Fränkl, E. Ueber Vorstellungs-Elemente und Aufmerksamkeit. Augsburg, 1905.

Fuchs, H. u. Haggenmüller, A. Studien und Versuche über die Erlernung der Orthographie. *Schiller's Sammlung von Abhdl. aus dem Gebiete der päd. Psychol.,* II. Bd., 4 H. (1898).

Hawkins, C. J. Experiments on Memory Types. Psychol. Rev., IV., 289–294 (1897).

Huey, E. B. The Pedagogy and Psychology of Reading. New York, 1908.

Kirkpatrick, E. A. An Experimental Study of Memory. Psychol. Rev., I, 602–609 (1894).

Lay, W. A. Führer durch den Rechtschreib-Unterricht. Wiesbaden, 2 Auflage, 1899.

—— Anschauungs- und Gedächtnistypen in Volksschul- und Seminarklassen. Experimentelle Untersuchungen zur Vertiefung des Prinzips der Anschauung. Leipzig, 1903.

—— Experimentelle Didaktik. Ihre Grundlegung mit besonderer Rucksicht auf Muskelsinn, Wille und Tat. 1. Allgemeiner Tl., Wiesbaden, 1903.

Lobsien, M. Die Grundlagen des Rechtschreibunterrichtes. *Pädagogische Studien.* Neue Folge, XXI. Bd., 1–20, 81–109 (1900).

MacDougall, R. Recognition and Recall. *Journ. Philos., Psych., and Sci. Meth.,* I., 229–233 (1904).

Pedersen, R. H. Experimentelle Untersuchung des visuellen und akustischen Erinnerungsbilder, angestellt an Schulkinder. *Archiv f. d. ges. Psychol.,* IV. Bd., 520–534 (1905).

Pohlmann, A. Experimentelle Beiträge zur Lehre von Gedächtnis. Berlin, 1906.

SECOR, W. B. Visual Reading. A Study in Mental Imagery. *Am. Journ. Psych.*, XI, 225–236 (1899–1900).

SMITH, T. L. On Muscular Memory. *Am. Journ. Psych.*, VII., 453–490 (1896–1897).

WHITEHEAD, L. G. A Study of Visual and Aural Memory Processes. PSYCHOL. REV., III., 258–269 (1896).

ON THE ANALYSIS OF THE FACTOR OF RECALL IN THE LEARNING PROCESS.

BY EDWINA E. ABBOTT.

CONTENTS.

I. The Nature and Aim of the Problem.

No one who has had experience in memorizing or in watching others memorize can have failed to observe the tendency of the average person when he is reading, to momentarily turn away from the material before him and to repeat it to himself without external aid. This tendency to recall appears whatever may be the material which is to be memorized or to whatever sense it is presented. The learner will often go through this procedure even when he knows he cannot remember the whole accurately; or, if the material is easily grasped, after he is able to repeat it perfectly and before dismissing it from his attention, he will repeat it to himself two or three times. The fact that this tendency is to be observed, however, does not justify us in believing without further evidence that recall is a desirable and helpful factor in the learning process. For, if experimental results in the field of memory have demonstrated anything, it is that the average person is not sure to use in memorizing the best and most economical methods to help himself. It is only by careful investigation under all conceivable conditions that we may obtain any adequate idea of the use and relative value of these factors which appear in the mental habits of normal people.

Certain results obtained in an experiment 'On the Analysis of the Memory Function in Orthography'[1] conducted in the

[1] See paper in this monograph.

psychological laboratory of the University of Illinois in the year 1907–08, led to the conclusion that the opportunity for recall, during or immediately after the learning process, was of great benefit to the individual. It has been the aim of the present experiment to determine more carefully the nature of the influence of this recall and the conditions under which it could be used most favorably. In other words, to determine, when a definite length of time is given in which to learn a given amount of material, whether it is of the greater advantage to spend all the time in actual perception of the material, or part of the time in perception and part in recall; and also whether the recall should be interspersed with the perception or should follow it immediately or after an interval. We have also attempted to make some analysis and explanation of the factors which are of influence in this recall period and particularly to determine the effect of localization.

The work already done along the line of economy of learning has shown that the relative value of many of the so-called methods of learning depend in a large measure on the memory type of the individual who is to use the method. A condition which would be of great advantage to a visually-minded individual might prove positively distracting to one of the auditory-motor type and again might have no appreciable effect on the individual of a mixed type. In view of this, in the present experiment care was taken to determine from introspective analysis the type of imagery of the subjects and in general the mental processes which they went through in learning the material presented to them.

II. Literature Related to the Problem.

In the experiment under discussion the total time devoted to learning was divided into two equal periods and separated by varying intervals. This procedure relates itself to the experiment of Jost,[2] who endeavored to verify the conclusions of Ebbinghaus.[3] Ebbinghaus found that sixty-eight successive

[2] 'Die Assoziationfestigkeit in ihrer Abhängigkeit von der Verteilung der Wiederholungen,' *Zeitschr. für Psychol. u. Phys. d. S.*, XIV., 436–472 (1897).

[3] *Ueber das Gedächtnis*, Leipzig, 1885.

repetitions of memory material have a less profitable effect than thirty-eight repetitions divided over three days. In his experiment Jost used the 'Esparnismethode' to determine whether there was greater or less advantage in presenting a series of twelve nonsense syllables thirty successive times, or in dividing the thirty repetitions equally over three days. His results showed that twenty-four hours after the final repetition there was more time saved in relearning when the first thirty repetitions had been divided. In an attempt to discover the reason for this superiority Jost investigated the laws of association by means of both the 'Treffer' and 'Esparnismethode' and comes to the following conclusions: First, that only the 'Treffermethode' can give a direct determination of the reproduction tendency of a series; second, that the two methods cannot give results at all comparable; third, that there are two fundamental laws of association as follows:

1. If two associations are of the same strength but of different age, a new repetition will have the greater value for the older one.

2. If two associations are of equal strength but of different age, the older one will decrease the less with time.

In all memory experiments in which the same material is presented repeatedly the factor of localization must enter to a greater or less degree. Pohlmann in experiments with school children and seminary students, in which nonsense material was presented with and without the opportunity for localization, concluded that this factor is an aid to memory and also that it is not necessarily of a visual character although apt to have more influence when of a visual nature.

The experiments of Witasek[4] and Katzaroff[5] bear more directly on our problem. Their purpose was to determine the relative effect of recitation and reading. Witasek presented groups of ten nonsense syllables by means of Wirth's memory apparatus at the rate of one syllable per second. The subject read the syllables aloud in trochaic rhythm during those series

[4] 'Über Lesen und Rezitieren in ihren Beziehungen zum Gedächtnis,' *Zeitschr. für Psychol. u. Phys. d. S.*, XLIV., 161–246 (1907).

[5] 'Le rôle de la récitation comme facteur de la mémorisation,' *Archives de Psy.*, VII. (1908).

designated as 'reading-series.' During the 'recitation-series' the syllables were pronounced aloud and the subject attempted to keep the rhythm and tempo the same as in the reading series. When the syllable was forgotten the subject was given ten seconds in which to recall it. If he failed to recall it during this time, *E* read the correct syllable to him and the recitation was resumed. When a wrong syllable was given the subject was stopped and the right one given him. The subjects were instructed never to go back over the syllables either during the reading or recitation series and to rule out associative links as far as possible. The order of series was as follows:

	A.	B.	C.	D.
(*a*)	XVI 5	VI 0	XI 10	XV 10
(*b*)	XI 5	VI 15	VI 5	XI 0
(*c*)	XVI 0	XI 15	XX 0	VI 10

The Roman numerals indicate the reading series, the Arabic numerals the recitation series. A, B, C and D were alternated to eliminate practice effect. In every case ten 'test-recitations' were given one hour after the completion of a series. A record was kept of the time consumed by every recitation and also of the helps given in the course of every recitation. From these data the following conclusions are drawn:

1. Recitations are in general far superior to readings in learning value.

2. Of recitation groups following one another the first has the greatest learning value and each succeeding group has less.

3. Of readings following one another the first has the greatest learning value and each succeeding reading has less.

4. The learning value of a recitation is higher if the association by which it is strengthened is made not through single readings but through reading and recitation.

Katzaroff used in his experiment the 'Treffermethode.' He presented groups of eight or ten pairs of nonsense syllables on a revolving drum which showed each couple for two seconds. Successive readings were separated by an interval of four seconds. During the presentation the subject was required to read the series aloud in trochaic rhythm. He was not to create artificial associations. During the recitation the first syllables

of every couple were presented in a different order from that of the reading presentation. The subject gave the corresponding syllable as quickly as possible. If he was unable to recall it or gave it wrongly, the right one was given to him. The series were presented with the following combinations of readings and recitations. The column to the left indicates the number of 'fundamental readings'; L signifies reading and R signifies recitation. The small number indicates the number of successive readings or recitations in a group.

			Final recall after
L 10	interval of 2 minutes	R1 L5	48 hours.
L 10	interval of 2 minutes	R1 R5	48 hours.
L 8	interval of 2 minutes	L7	72 hours.
L 8	interval of 2 minutes	R7	72 hours.
L 8	interval of 2 minutes	L7	72 hours.
L 8	interval of 2 minutes	R1 L6	72 hours.
L 4	interval of 2 minutes	L6	24 hours.
L 4	interval of 2 minutes	R6	24 hours.
L 4	interval of 2 minutes	R1 L1 R1 L1 R1 L1	24 hours.
L 4	interval of 2 minutes	L6	24 hours.
L 4	interval of 2 minutes	R3 L3	24 hours.
L 4	interval of 2 minutes	R2 L1 R1 L1 R1 L1	24 hours.

Katzaroff concludes that:

1. All the experiments show R superior to L in conservation, promptness and certainty of memory; we are justified in concluding that after a certain number of fundamental readings the recitation has a fixing value superior to that of an ordinary reading.

2. The extent of R's superiority varies according to the number and disposition of R in relation to L. The best combination appears to be a number of fundamental L's proportioned to the length of the series. Then at least two R's, then at least two L's to reinforce the series as a whole.

Katzaroff explains his results: first, by the fact that the mental attitude in recitation is active and one of constantly looking forward and never looking back, while in reading the attitude is passive, thus making recitation more favorable for the factors

of attention and the richness of association; and second, from the point of view of the cerebral force. The neural paths which are traced in the trial recitations are the same as those used in the final recitation. The centers and paths used in reading are not the same.

Meumann[6] has noted this natural tendency, referred to above, to make use of an immediate recall in connection with the learning process. In treating that phase of memory which constitutes the attentive impressing on the mind of sensory data, he states that " all sense impressions go through a double period of forgetting. The first is, in a measure, only a fading of the original impression and during this period the impression will be reproduced most easily and similarly will be most easily made enduring by a repetition of the stimulus. Therefore we see that it is important for the technique of the learning of sensory material that the active impression be made while the stimulus is still present or immediately thereafter. We proceed thus unconsciously when we wish to make a lasting impression on our minds of some complicated material. We reproduce it while the object is still before us or we close our eyes a moment and then bring our attention back to the object after we have endeavored to reproduce it unaided."

It is obvious that Witasek and Katzaroff in introducing recitation into their period of recall made of it an entirely different process from that described by Meumann. The factor emphasized by Katzaroff in his explanation of the efficacy of recitation is the attitude of ' never looking back and constantly looking forward.' This factor is in direct opposition to that of ' immediate imaging ' by which Meumann explains the value of immediate recall. Since it is obvious that both these factors cannot enter at once into the mental process of a subject who is given an opportunity for immediate recall, the question remains, which factor is used when the subject is left free to use the recall period as he likes and which is of the greater value for learning. It shall be our purpose to show that the use and relative efficiency of these factors depend on the memory type of the individual who is doing the learning.

[6] *Ökonomie und Technik des Gedächtnisses,* Leipzig, 1903.

III. Method of Procedure.

The method used in conducting the present experiment differs in a few particulars from that used in preceding experiments bearing on the same problem. Other experimenters have required their subjects to make their recall entirely in the form of recitation. This would necessarily bring the vocal and auditory factors into strong prominence with all subjects and the results would in all probability be influenced by the individual type of the subjects. Since it was the purpose of the experiment under discussion to discover the factor or group of factors to which the influence of the recall period might be traced, the subjects were given the time for recall without directions as to how it should be used and through introspection the attempt was made to discover the factors present.

Katzaroff in his experiment on the influence of recitation used the 'Treffermethode,' that is, he presented nonsense syllables in pairs for the learning series, and for the recitation and recall series he presented only the first of each pair and the subject was instructed to give the accompanying syllable. It would appear that in seeking for the accompanying syllable the subject has two distinct courses open to him. He may remember it by means of its association with the syllable he is looking at; or he may remember it by some association in the column of syllables to be recalled. Since these two courses may introduce a complexity of factors into the recall we preferred to use in our experiment the more simple method of recalled members.

The most noticeable difference in our method from that of other investigators lies in the fact that in no other experiment has there been any definite attempt to determine the individual type of the subjects and to use this knowledge in the interpretation of the numerical results. So much has been said and will appear later concerning the importance of this knowledge that it is sufficient to state here that throughout our experiment this determination has been done in the case of every subject with the greatest care.

The material used in the experiment was of two kinds, nonsense syllables and words. The nonsense syllables were made up according to the method of Müller and Schumann and pre-

sented in groups of thirty. The words were chosen at random from an English dictionary and included nouns, verbs and adjectives. They were never over four syllables in length. They were presented in groups of sixty. Both words and syllables were typewritten in columns on sheets of thin white cardboard and were so spaced that when the cardboard was fitted into the slide of a 'Jastrow fall shutter,' the words or syllables were exposed before a narrow opening, either one immediately after the other, or with a blank interval between. This fall apparatus was fitted with an electro-magnetic release. The electric circuit which controlled the falling shutter contained a mechanical interrupter or contact mechanism in the form of a toothed wheel. By the introduction of wheels of different forms, containing different numbers of teeth and different distances between the teeth, it was possible to vary the temporal relation of the exposure at will. Thus the stimulus word or syllable could be exposed for one second with an interval of three seconds or with no interval. This mechanical interrupter was in turn controlled by an electric pendulum (Zimmermann's *Kontaktuhr*). The word or syllable when it was exposed on the shutter was reflected through a lens onto a ground glass screen in a large camera-shaped box. At the end of the box opposite the lens was an opening of a convenient size and the subject sat before the box with his eyes on a level with this opening. The box was so made that the focus could be adjusted for any individual. The system of lenses had a diameter of five centimeters and a focal length of thirty-two centimeters.

It will be seen from the table on page 167 that in series a, b, c, d, e, f, h, i and j, sixteen minutes were devoted to the entire process of learning, while g and k received only eight minutes. Also that in the series a, b, c and g there is no opportunity given for recall, the learning periods being consumed in *Einprägung;* that in series d, e and f half the time is given to recall and it comes after the *Einprägung* and that in series h, i, j and k three fourths of the time is given to recall and it is interspersed with the *Einprägung* during the three seconds interval between presentations.

These series were presented in two different ways. The

first way, which we have termed the 'regular order,' consisted in keeping the order of words or syllables in a group constant throughout the presentation time. The second way, termed the 'mixed order,' differed from the former in that a group of words or syllables was never presented twice in the same order.

The groups of words and syllables were presented in eleven different kinds of series as follows:

Series.	First 8 minutes spent in	Exposure time per word or syllable.	Interval between words or syllables.	Interval between 1st and 2d learning period.	Second 8 minutes spent in
a	visual Einprägung[7]	1″	0	1′	Einprägung
b	"	1″	0	15′	"
c	"	1″	0	45′	"
d	"	1″	0	1′	Recall
e	"	1″	0	15′	"
f	"	1″	0	45′	"
g	"	1″	0		
h	Einprägung and recall	1″	3″	1′	Einprägung and recall
i	"	1″	3″	15′	"
j	"	1″	3″	45′	"
k	"	1″	3″		

In both series the final recall was made four hours after the learning was completed. The subject was required at this time to write down all the words and syllables he could remember. He was given fifteen minutes for each group and at the end of that time those correctly recalled were counted and recorded. Only one group of words was given during one day to each subject. The series were not given in the order described, but in such an order that practice effect would be equally distributed for the three different sorts of series; that is, for the a, b, c group, in which there was no opportunity for recall, the d, e, f group in which the recall all came after the *Einprägung* and the h, i, j group in which the recall was interspersed with the *Einprägung*. During the one, fifteen and forty-five-minute intervals the subjects were not allowed to

[7] 'Einprägung' is the German word which designates the process of attending to sensory materials with a view to remembering it. There is no term in English which so aptly describes the process, and we have used the term 'visual Einprägung' to designate the time spent by our subject in attending to material visually presented with the view to remembering it.

think of the material. The fifteen and forty-five-minute intervals were usually consumed in taking other groups or in presenting groups to another subject.

The subjects were given certain instructions. During the presentation of the groups in series a, b, c, d, e, f and g the subject was not to form any associative links between the words or syllables and while one word or syllable was before him he was not to think of any other. We endeavored in this way to prevent as far as possible any attempt at reimaging. During the recall period in the d, e, f series the subject was allowed to recall the group in any terms of imagery he wished and to associate the words or syllables in any way he wished. But he was not allowed to pronounce them aloud or to write them down. The recall period of three seconds in series h, i, j and k the subject was allowed to spend as he wished, and also in these series he was allowed to form any associations he wished to between the different members of the group. He was also instructed not to think of the material during the period between the learning and the final recall.

Throughout the experiment careful introspections were taken of the processes and imagery used both in the learning and recall. These were supplemented by questions from the experimenter with the particular object in mind of throwing light on the individual type of the subject. The subjects were students from the psychological laboratory at the University of Illinois and were five in number.

IV. Results.

1. *Introspective Results.*

The numerical data when interpreted in the light of the introspective results take on an entirely new significance from that which appears when they are studied by themselves. Hence it is of the greatest importance before presenting the actual results of the experiment, to give a complete description of the type of procedure of each individual as it has been disclosed by means of the subject's own analysis. The procedure in the case of *Einprägung* seems to differ very slightly for all

the subjects. They all look at the word or syllable attentively. Most of them are conscious of whispering the word or of employing 'inner-speech.' One of a marked visual type, however, repeatedly asserts that she is unconscious of any pronunciation whatever. She simply 'looks at the word and lets it soak in.' When one word passes from the field, the attention is focused on the next that appears.

When we come to the recall in the d, e, f series, in which half the total learning time is given for recall and comes after the presentation is completed, we find that each individual constructs what he can of the group in terms of imagery most natural to him and then spends the remaining time reimaging and in forming more or less artificial associative links between the words or syllables. It is significant that these links are said to be formed after the first reimaging. The only exception in this general course of procedure is found in the case of *Y* (strong visual type), who merely reimages repeatedly and does not form associative links between the words or syllables.

It is when we come to the h, i, j group, in which the recall is interspersed with the *Einprägung* that we find the greatest deviation in general procedure. Four of the subjects spend the interval of three seconds of recall after each term of the group in thinking of the term which has been seen, in reimaging it according to their several types, in imaging some concrete object, perhaps sometimes in running back over the last two or three terms seen. For these cases the procedure is clearly that described by Meumann and referred to earlier, namely, that of catching the image just as it is fading from consciousness after the actual presentation, when it may most easily and most accurately be revived, and impressing it upon the mind. During this period there are also to some extent associative links formed, such as words and phrases which fit together by meaning, or rhyme or jingle. These are repeated together and they thus fall into groups. This associative tendency we find lacking, however, in subject *Y*. This subject reimages the last term usually and with few exceptions in concrete visual form, but there is little or no association between terms. Entirely different from this kind of procedure is that of the fifth subject,

W, whose introspections follow in his own words. "The process of learning in this kind of a series is thus,—The first time the list of words is seen for each word, some image is called up and connected with the image of the next word. The word is also pronounced. After the first presentation, as soon as one word has disappeared I try to think of the next word. If I can, I say it over to myself. If not, I wait for it attentively. I put equal time on every word, for I never run back or forward in groups but always think of the word which is to follow immediately. The process is the same for the syllables, except that there is no concrete imagery for them outside the visual imagery of the syllable itself. These are sometimes spelled through and sometimes pronounced." This method of learning was possible only in the 'regular order.' In the 'mixed order' this subject re-imaged the last word presented just as the other did. It will easily be seen that in the 'regular order' series this subject does not use at all the immediate reviving of the image of the term just seen, which revival is of such importance to the others. He has literally transformed the recall series into a recitation series such as those used in the experiments of Katzaroff and Witasek, the only difference being that he 'recites' in the imagery which he is most accustomed to using in his thinking, instead of in vocal and auditory terms, which he may or may not be accustomed to using. These general distinctions given, we will present the more detailed descriptions of the individual type of the five subjects and their procedure in the different kinds of series.

V. This subject makes use both of 'inner-speech' and concrete visual imagery in his thinking. In the a, b, c and g series, when there is no chance to think the words together, he pronounces them and looks at them attentively while they are being presented. Sometimes the concrete visual appears. In the final recall there is an attempt to revive whatever imagery there may be left of the word or syllable, but the subject seems to have poor control over this imagery. When trying to recall, he feels that the words are there and that they would be recognized instantly if presented. They seem to be just on

the threshold, but there is nothing to get hold of them with. There is no handle. The predominant character of this imagery seems to be visual. "There seems to be a visual image," he says, "but it is one that moves very fast and there is not time to get any one word." Again, "In all cases of the mixed order the visual image of the word is used exclusively. The word is always pronounced when seen but this seems to be no aid in final recall." During the recall period in the d, e, f series, the subject states that the visual image and inner pronunciation of those terms of the group which are recalled, appear simultaneously and all the terms which can be recalled are then linked together by some meaningful association. The process in the h, i, j and k series has already been described. It would appear then that the general character of *V's* imagery is visual and also that the mere mechanical reproduction of sensory data in terms of imagery is difficult for him.

W. This subject is of a distinct verbal type. We do not find the concrete entering to a marked degree and when it does it appears to accompany and not aid either the learning or recall. This verbal imagery is motor-auditory and the *Einprägung* of a word or syllable is always accompanied by pronunciation. The imagery used in the recall period is decidedly of a mixed type and is in the main verbal. The process of learning seems to be one of reinforcing the verbal impression with various kinds of imagery, occasionally associating it with some concrete image or with some other word or syllable in the series and usually localizing it in the series either visually or by motor aid.

X. This is a subject who is predominantly motor-auditory, but who also uses visual imagery to a large extent. In the h, i, j series the recall interval is used for repeating the term last seen and 'so fixing it in my mind.' Visual localization is employed frequently and if the first term of a column is gone, the other terms in that column are often lost entirely.

Y. This subject is of a very strong visual type who 'never pronounces a word or syllable in learning, merely tries to absorb the visual picture.' Concrete visual imagery also appears often. The words and syllables suggest these concrete images, but are

rarely linked with other words or syllables in the group. During the recall period the last term seen is visualized and sometimes the last several terms are run over. In the final recall the subject remembers them ' by seeing them in the mind and remembering them as they appear on the screen.' The ' mixed order ' impressed this subject as being particularly unfavorable. The concrete visual appears much more in evidence in the ' mixed order,' as the serial localization is inhibited.

Z. This subject was given only a few series, to determine if possible the effect of localization, and is a remarkably clear case of the necessity for introspective evidence as a means of interpreting objective results. The procedure was as follows:

For the mixed order the words are classified according to meaning and syllables according to resemblance and " the whole feeling is one of trying to get them through as many of the senses as possible." Concrete imagery rarely enters, although it sometimes does and is always a help when it does.

In the regular order all these aids are thrown overboard completely and a visual map of the card is made. In the recall visual imagery is used exclusively. These results show how completely the change of one objective factor may change the entire mental attitude with which the subject attacks the problem and cause entirely new processes to be used. It is folly to suppose that our mental processes are made up of factors which bear a definite relation point for point to the objective factors of the experiment and that by changing one objective factor we will merely change a corresponding factor or group of factors in the mental process. On the contrary we may by that one objective change substitute an entirely new set of factors in the mind of the subject.

2. *Objective Results.*

The tables below are given in terms of the per cent. of correctness.

Table I. presents the various series as described above for both the regular and the mixed order. The subjects tested are indicated at the right, each subject being tested on both words and syllables, and subjects *W*, *Y* and *Z* are tested for both the regular and the mixed order.

TABLE I.

Series.	Regular Order.											Subject.
	a	b	c	d	e	f	g	h	i	j	k	
Words	23	23	24	23	33	25	23	41	59	42	8	*V*
Syllables	42	38	40	35	40	17	22	68	92	70	47	
Words	8	8	13	29	12	8	5	97	98	97	62	*W*
Syllables	20	15	12	20	30	27	8	97	97	98	62	
Words	15	28	23	28	15	18	13	31	34	30	18	*X*
Syllables	13	13	22	22	17	18	5	30	27	48	10	
Words	67	78	83	48	42	43	28	53	55	17	23	*Y*
Syllables	67	53	70	67	63	50	57	63	67	53	43	
Words	54			61				56				*Z*
Syllables	60			50				55				
	Mixed Order.											
Words	10	13	17	13	12	7		20	17	8		*W*
Syllables	17	23	27	40	20	17		10	13	7		
Words	28	25	20	33	17	17		27	18	27		*Y*
Syllables	67	10	40	40	37	20		30	43	37		
Words	55			49				53				*Z*
Syllables	52			68				62				

TABLE II.

Series.	a	b	c	d	e	f	Subject.
Words	0	0	1	0	10	2	*V*
Syllables	20	16	18	13	18	—5	
Words	3	3	8	24	7	3	*W*
Syllables	12	7	4	12	22	19	
Words	2	15	10	15	2	5	*X*
Syllables	8	8	17	17	12	13	
Words	39	50	55	20	14	15	*Y*
Syllalbes	10	—4	13	10	6	—7	

Table II. was derived from Table I. by substracting the results obtained in series g, from the results obtained in series a, b, c, d, e and f, respectively. This second table, therefore, represents what is gained by the added eight minutes of learning or recall over the time taken for the simple *Einprägung*. In some instances there is a minus quantity. Only the regular order was so treated.

Table III. gives the results of the words and syllables combined, as shown separately in Table I., but for the regular order only.

Table IV. gives a comparison of the regular and of the mixed order for syllables and words combined and was derived from Table I. The letter T in Tables III. and IV. indicates the average of the totals for a, b and c; d, e and f; and h, i and j, respectively.

TABLE III.

Series.	a	b	c	T	d	e	f	T	h	i	j	T	g	k	Subject.
	29	28	29	29	27	35	22	29	50	70	51	56	23	21	*V*
	12	11	12	11	26	18	14	19	97	98	97	97	6	62	*W*
	14	23	23	20	26	16	18	20	31	32	36	35	10	16	*X*
	67	70	79	72	54	49	46	49	57	59	29	48	38	30	*Y*

TABLE IV.

	a	b	c	T	d	e	f	T	h	i	j	T	Subject.
Regular order	12	11	12	11	26	18	14	19	97	98	97	97	*W*
Mixed order	12	17	20	16	22	14	10	15	17	16	8	13	
Regular order	67	70	79	72	54	49	46	49	57	57	29	48	*Y*
Mixed order	41	50	27	39	36	23	18	26	28	27	30	28	
Regular order	56	—	—		57	—	—		56	—	—	—	*Z*
Mixed order	54	—			56	—	—		56	—	—	—	

In comparing the efficiency of memory for words and syllables, we would expect for several reasons to find the syllables possessing an advantage over the words. Inasmuch as the groups of words were twice as great in number as the groups of syllables and the time of presentation was constant, each group of syllables was actually presented twice as many times as its corresponding group of words. The syllables, too, are shorter and simpler to perceive. In general we find the objective results (Table I.) show that this advantage exists for the syllables. The exception we find where we would expect to, namely, in the results of *W* for the h, i and j series, where imagery played an insignificant rôle in the learning process. We would also expect that this superiority would be most marked in the case of *Y*, our strong visual subject, who uses imagery exclusively in learning and here again to an extent and particularly in the mixed order the objective results justify our expectations. In this case, also, it is significant that the super-

iority decreases as the number of presentations of both words and syllables increases.

Comparing the one, fifteen and forty-five minute intervals between learning periods (Table I.), we obtain no conclusive results except in the d, e and f series where there is some uniformity in favor of the one minute interval. One subject, however, finds the fifteen minute interval more favorable. We may say in the main that when the recall comes after the *Einprägung,* the sooner it comes the better.

When we compare the results for g with those for d, e and f we obtain exactly the amount the recall adds to the permanent effect of eight minutes of *Einprägung* (Table II.). Although there is no uniformity the striking point is that there are only three cases out of the twenty-four in which *something* is not added and that for *V, W* and *X* in the majority of cases the recall adds as much as or *more* than the added eight minutes of *Einprägung* in *a, b* and *c.* As we would expect we find that in the case of *Y*, although the recall adds something, it is less than what the same amount of additional *Einprägung* adds.

The most significant comparison lies in the figures for the three groups a, b, c; d, e, f and h, i, j (Table III.). In subject *W*, who as has been explained before, makes of this kind of series a mental recitation we find an immense advantage for h, i, j over a, b, c or d, e, f. For *V* and *X*, who use associative links, or rather groupings, to some extent to reinforce their imagery, we find the h, i, j series has a distinct advantage over the a, b, c and d, e, f series, but this advantage is slight. For subject *Y* who uses little or no associative help but depends on strong visual imagery, we find the h, i, j series is distinctly unfavorable and those series in which the groups are seen the greatest number of times have a great advantage.

Comparing the effect of the mixed order with that of the regular order (Table IV.), we find in *Y's* results the mixing of the order has an unfavorable effect and this effect increases as the number of actual presentations increases. It is natural in the case of a pronounced visual type such as *Y*, that the more the order of presentation is changed the more confused he

would become. On the other hand in the a, b, c series of *W* the mixed order seems to have a slight positive advantage over the regular order. This may be due either to a more strained attention or to practice effect. In the d, e, f series we find a slight advantage in favor of the regular order. In the h, i, j series, however, the advantage is overwhelmingly in favor of the regular order. It should be noted again that the procedure in the h, i, j series, which is of such a great advantage to *W* in the regular order, is impossible in the mixed order.

In studying the results of the tests with *Z* who, it will be remembered, changes the whole process of learning to suit either the mixed or regular order of presentation, we find that she apparently adapts herself to the mixed order with as little effort as to the regular order.

Above all, the tables show the consistent and characteristic manner in which the memory determines and explains the efficacy of a given factor in the learning process. That the opportunity for recall is of aid in learning we cannot doubt, but the extent of this aid and the explanation of why it is an aid differs widely for different individuals. For some individuals the opportunity to recall is used mainly to reimage, and as we find this is an aid to memory we must agree with Meumann in emphasizing this immediate retrospect as a basis for the explanation of the efficacy of recall. Another individual, however, may discard reimaging entirely and use the recall as a means for an 'inner-speech' recitation, and as we find this of great assistance in learning we must agree with Katzaroff in his emphasis on the value of the 'mental attitude of constantly looking forward.' Again we must note that that extreme type in whose learning processes we find relatively slight traces of association is more benefited by repeated presentation than by the opportunity to reimage, while for the opposite type repeated presentations seem to have little effect. We must go back to the type of the individual to explain the processes and relative efficiency of this factor of recall.

V. Conclusion.

We are led then both by our introspective and objective results to conclude:

1. That the factor of recall is always an aid in the learning process.

2. That when recall comes after the *Einprägung* of the material, immediate recall is of more value than delayed recall and its value decreases as the delay increases in length.

3. That the recall is of greater value when it is interspersed with the *Einprägung*.

4. That localization is one of the factors which go to make recall an aid to memory, but that the relative importance of this factor is determined by individual type.

5. That the relative value of recall and *Einprägung* depends on individual type; that for the individual of strong 'inner-speech' tendency who depends little on immediate reimaging and in recall goes through the same processes that one would in recitation, the recall is of great value and the *Einprägung* of comparatively little importance, while for the type which depends on immediate reimaging during recall the *Einprägung* is of relatively greater importance than the recall in proportion as the factor of association is less effective in the learning process.